DX Skill Landscape & Timeline - 2026-06-07

Table of Contents

Introduction

This site aims to provide a comprehensive overview of concepts, techniques, tools, platforms, and frameworks related to DX (Digital Transformation), featuring Software Development and DevOps spaces, spanning the following 12 categories:

- 01 - Business Transformation
- 02 - Web Application Development
- 03 - Cloud & Cloud-Native Computing
- 04 - Security & Privacy
- 05 - Data Science & Engineering
- 06 - AI, Machine Learning & LLM
- 07 - Fundamental Developer Skills
- 08 - OS & Network Basics
- 09 - Programming Concepts & Paradigms
- 10 - Advanced Programming
- 11 - Specialized Development Domains
- 12 - Personal Skills

Timelines

In addition to the skill categories above, this site provides chronological timelines documenting significant technology events, product releases, and industry milestones from 1930 to the present. Each entry is categorized by domain using emojis:

- ¬ Business Administration, Development Methodology, Management
- ¬ Web Technology incl. Web Frameworks
- ¬¬ Cloud, Cloud Native, Container, DevOps/SRE
- ¬ Security, Privacy
- ¬ Malware, Virus, Security Incident
- ¬ Data Science, Databases, Data Platforms
- ¬ AI, Machine Learning, Large Language Models
- ¬¬ Shell, Scripting, Terminal, IDE, Developer Productivity
- ¬¬ System Administration, OS, VM, Network Infrastructure
- ¬ Programming Paradigms, Programming Concepts, Libraries
- ¬ Others

These timelines help trace the evolution of technologies listed in the skill sections and provide historical context for understanding current trends in software development and digital transformation.

Coverage for IPA DSS-P

This site's skill list attempts to cover all of the **Digital Skills Standard for Promotion (DSS-P) v2.0** defined by IPA. Under each subsection of each section page, the most relevant DSS-P skill names are listed.

The IPA (Information-technology Promotion Agency, Japan) is a policy implementation agency under the jurisdiction of Japan's Ministry of Economy, Trade and Industry (METI). It plays a central role in Japan's national IT strategy, including **Human Resource Development** (administering national IT examinations), **Information Security Measures**, and establishing **Guidelines for Digital Transformation (DX)**.

The **DSS-P** referenced in this document is a public standard defined by the IPA to accelerate DX in Japanese companies. It is widely adopted by many Japanese enterprises as a benchmark for talent development and hiring.

The table below shows the primary DSS-P category covered by each skill section:

Section	Title	Primary DSS-P Category
01	Business Transformation	1. Business Transformation
02	Web Application Development	3. Technology
03	Cloud & Cloud-Native Computing	3. Technology
04	Security & Privacy	4. Security
05	Data Science & Engineering	2. Data Preparation & Utilization
06	AI, Machine Learning & LLM	2. Data Preparation & Utilization
07	Fundamental Developer Skills	3. Technology
08	OS & Network Basics	3. Technology
09	Programming Concepts & Paradigms	3. Technology
10	Advanced Programming	3. Technology
11	Specialized Development Domains	3. Technology
12	Personal Skills	5. Personal Skill

Principles

This site is built on the following principles:

AI-Driven Development & Human Interaction: As AI agents take over increasingly detailed tasks in software development, the ability to articulate requirements precisely becomes critical. This demands a broad, cross-domain knowledge base — the wider one's understanding of technologies and concepts, the more effectively one can direct AI to produce the right outcomes. At the same time, Digital Transformation involves significant organizational and individual change, so elements from human sciences such as sociology and psychology are incorporated. Understanding human behavior is crucial for driving transformation.

Prioritizing Openness: Open Source Software (OSS) and open formats are favored over proprietary alternatives. This minimizes restrictions and vendor lock-in, which can impede agile decision-making. Furthermore, the availability of source code significantly aids in troubleshooting. Cloud services are included where essential.

Language Agnosticism: Programming languages are treated primarily as tools. Since modern developers can easily work with multiple languages, multi-language workflows have become routine. The focus is on selecting the most suitable language for a specific problem domain or cultural context.

Primary References

These resources serve as the primary references for the content on this site.

- Level Up Coding - A Medium publication covering software engineering, DevOps, and cloud topics
- ITNEXT - A Medium publication focused on IT, web development, and DevOps practitioners
- FAUN - A Medium publication dedicated to cloud native, DevOps, and developer content
- Thoughtworks Technology Radar - A curated guide to techniques, tools, platforms, and languages worth adopting, trialing, or avoiding
- Developer Roadmaps - Community-driven roadmaps and learning paths for various engineering roles
- Golang Weekly - A weekly newsletter covering Go language news, articles, and projects
- Ruby Weekly - A weekly newsletter covering Ruby language news, articles, and projects
- Postgres Weekly - A weekly newsletter covering PostgreSQL news, articles, and tools
- Tony Lixu on Medium - Articles on cloud infrastructure, Kubernetes, and DevOps engineering

01 - Business Transformation

Project Management

:::note[Relevant DSS-P Skills]

- 1. Business Transformation > 1.3 Management of Transformation Activities > Program / Project Management
- 1. Business Transformation > 1.2 Product Management > Product Scope and Priority Management

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==== Project Planning & Estimation

- Project management - The process of leading the work of a team to achieve all project goals within the given constraints
  - Critical chain project management - A method of planning and managing projects that emphasizes the resources (people, equipment, physical space) required to execute project tasks
  - Gantt Chart - A bar chart illustrating a project schedule, displaying tasks on the vertical axis and time intervals on the horizontal axis, with bar widths indicating activity durations and often showing task dependencies
  - Program evaluation and review technique (PERT) - A statistical tool used in project management to analyze and represent the tasks involved in completing a project
  - Work breakdown structure - A deliverable-oriented breakdown of a project into smaller components
  - RACI matrix - A responsibility assignment matrix (RAM)… describes the participation by various roles in completing tasks or deliverables for a project or business process
    - Responsible, Accountable, Consulted, Informed
  - Software development effort estimation - The process of predicting the most realistic amount of effort (expressed in terms of person-hours or money) required to develop or maintain software based on incomplete, uncertain and noisy input
    - Hofstadter's law - A self-referential adage about the difficulty of accurately estimating the time required to complete complex tasks
    - Three-point estimation - A technique used in project management to estimate the likely duration or cost of an activity
    - Planning poker - A consensus-based, gamified technique for estimating, mostly used for timeboxing in Agile principles
  - Systems development life cycle (SDLC) - A conceptual model used in project management that describes the stages involved in an information system development project

Prioritization

- Prioritization - The activity that arranges items or activities in order of urgency

  - RICE - A simple scoring system for product prioritization that stands for Reach, Impact, Confidence, and Effort
  - Kano model - A theory for product development and customer satisfaction developed in the 1980s by Noriaki Kano
  - MoSCoW method - A prioritization technique used in management, business analysis, project management, and software development

Tools

- Issue Tracking & Project Management
  - Jira - A software application used for issue tracking and project management that helps teams plan, assign, track, report, and manage work
    - JiraCLI - An interactive command line tool for Atlassian Jira that will help you avoid Jira UI to some extent
  - Asana - The platform for human and AI collaboration that helps teams coordinate work and keep projects moving
  - Notion - An all-in-one workspace for notes, docs, wikis, projects, and collaboration that combines knowledge management with task and project tracking
  - Trello - A visual collaboration tool that creates a shared perspective on any project using boards, lists, and cards to organize tasks
  - Airtable - A platform that combines the flexibility of a spreadsheet with the power of a database to help teams manage their work
  - Fizzy - A modern spin on kanban for tracking anything such as bugs, issues, ideas, and small projects
  - GitLab Issue Board - A user interface that displays issues in columns that correspond to their workflow statuses
  - GitLab Service Desk - A feature that enables you to connect with users through email, without requiring them to have a GitLab account
  - Azure Boards - A service that provides a customizable platform for managing work items, allowing teams to collaborate effectively and streamline their workflow
  - GitHub Issues - A tracking tool that helps you manage your work on GitHub
  - Redmine - A free and open source, web-based project management and issue tracking tool
- Team Collaboration & Communication
  - Slack - A cloud-based team collaboration platform that brings conversations, tools, and files together in one place
  - Microsoft Teams - A collaboration platform that combines workplace chat, meetings, file storage, and application integration
  - Discord - A voice, video, and text communication service used by communities, friend groups, and businesses to stay connected

- Mattermost - An open source collaboration platform for developers, offering secure messaging, project management, and workflow orchestration
- Zoom - A video communications platform that provides video meetings, voice calls, webinars, and chat
- Twilio - A customer engagement platform that provides programmable communication tools for making and receiving phone calls, sending and receiving text messages, and performing other communication functions
- Dropbox - A file hosting service that offers cloud storage, file synchronization, personal cloud, and client software
- Box - An enterprise cloud content management platform that enables organizations to securely manage and share content while collaborating with internal and external users

Standards & Maturity

- CMMI (Capability Maturity Model Integration) - A process level improvement training and appraisal program
- ISO/IEC 12207 (Software life cycle processes) - The international standard for software lifecycle processes that defines all the processes required for developing and maintaining software systems
- ISO/IEC 15288 (System life cycle processes) - The technical standard in systems engineering which covers processes and lifecycle stages
- ISO/IEC 15504 (Process assessment) - A set of technical standards documents for the computer software development process and related business management functions

Product Management

:::note[Relevant DSS-P Skills]

- 1. Business Transformation > 1.2 Product Management > Requirement Analysis and Management
- 1. Business Transformation > 1.2 Product Management > Product Vision / Roadmap Formulation
- 1. Business Transformation > 1.2 Product Management > Marketing
- 1. Business Transformation > 1.3 Management of Transformation Activities > Product Lifecycle Management

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==== Product Strategy

- Product management - The business process of planning, developing, launching, and managing a product or service
- Lean startup - A methodology for developing businesses and products that aims to shorten product development cycles and rapidly discover if a proposed business model is

viable

- Crowdfunding - The practice of funding a project or venture by raising money from a large number of people, typically via the internet
- Business model - The rationale of how an organization creates, delivers, and captures value, in economic, social, cultural or other contexts
  - Direct-to-consumer - A business model of selling products directly to customers and thereby bypassing any third-party retailers, wholesalers, or intermediaries
  - Subscription business model - A business model in which a customer must pay a recurring price at regular intervals for access to a product or service
  - Business model canvas - A strategic management template for developing new or documenting existing business models
  - Lean Canvas - A one-page business modeling tool for entrepreneurs to quickly outline their business idea
- IT service management - The activities that are performed by an organization to design, build, deliver, operate and control information technology (IT) services offered to customers
- Tools
  - Linear - A purposeful tool for product development, featuring issues, cycles, and product roadmaps
  - Aha! - A suite of product development software that helps teams build and market products customers love
  - ServiceNow - A cloud-based, AI-powered platform for digital workflows that connects people, functions, and systems across the enterprise
  - Gamma - A new medium for presenting ideas, powered by AI
- Related Standards
  - ISO/IEC 20000 (Service management) - The international standard for IT service management that specifies the requirements for establishing, implementing, maintaining, and continually improving a service management system
  - ITIL (Information Technology Infrastructure Library) - A set of detailed practices for IT service management (ITSM) that focuses on aligning IT services with the needs of business

Requirements Analysis

- Requirements analysis - The process of determining the needs or conditions to meet for a new or altered product or project, taking account of the possibly conflicting requirements of the various stakeholders
  - Requirement - A documented need of what a product or service should be or do
    - Non-functional requirement - A requirement that specifies criteria that can be used to judge the operation of a system, rather than specific behaviors

- Related Standards
  - ISO/IEC 25010 (Systems and software Quality Requirements and Evaluation) - The international standard for systems and software quality requirements and evaluation that defines system and software quality models

Marketing & Customer Experience

- Marketing - A process of acquiring, satisfying, and retaining customers, often involving creating, communicating, delivering, and exchanging offerings that have value for various stakeholders
  - SEO - The process of improving the quality and quantity of website traffic to a website or a web page from search engines
    - Google Search Central - The home for everything you need to help users find your site on Google Search
  - Marketing mix - A foundation model for businesses, historically centered around product, price, place, and promotion
  - Fear of missing out (FOMO) - The feeling of apprehension that one is either not in the know about or missing out on information, events, experiences, or life decisions that could make one's life better
  - Fear, uncertainty, and doubt (FUD) - A manipulative propaganda tactic used in sales, marketing, public relations, politics, polling, and cults
  - Tag management
    - Google Tag Manager - A tag management system that allows you to quickly and easily update measurement codes and related code fragments known as tags on your website or mobile app
  - Analytics tools
    - Google Analytics - The go-to platform for millions of website and app owners seeking to gain a deeper understanding of their website and app performance
    - Plausible - Intuitive, lightweight and open source web analytics
    - Umami - A simple, fast, privacy-focused alternative to Google Analytics
    - Ackee - Self-hosted, privacy-focused analytics tool for those who care about privacy
  - User experience research
    - Card sorting - A method used to help design or evaluate the information architecture of a site
    - A/B testing - A way to compare multiple versions of a single variable, for example by testing a subject's response to variant A against variant B, and determining which of the variants is more effective
    - Diary studies - A research method in which people record their experiences and activities over time

- Advertising
  - Indicators
    - Click through rate - The ratio of users who click on a specific link to the number of total users who view a page, email, or advertisement
    - Conversion rate - The percentage of users who take a desired action
  - Platforms
    - Google Ads - An online advertising platform where advertisers bid to display brief advertisements, service offerings, product listings, or videos to web users
    - Google AdSence - A program run by Google through which website publishers in the Google Network of content sites serve text, images, video, or interactive media advertisements that are targeted to the site content and audience
- Experiment platform
  - Optimizely - A leading digital experience platform (DXP) that provides a single, unified platform that offers you the scalability and security you need to drive your business into the future
- Email Distribution & Marketing
  - SendGrid - A cloud-based email delivery platform that provides reliable transactional and marketing email delivery at scale
  - Mailchimp - An all-in-one marketing platform for small businesses that helps manage and talk to clients, customers, and audiences with email marketing
  - listmonk - Self-hosted newsletter and mailing list manager
  - BillionMail - An open-source MailServer and email marketing solution that is fully self-hosted and dev-friendly
- Concepts and Frameworks
  - Brand - A name, term, design, symbol or any other feature that distinguishes one seller’s goods or service from those of other sellers
  - Customer experience - A customer’s cognitive, emotional, sensory, and behavioral responses during all stages of interaction with a product or service
  - Customer service - The assistance and advice provided by a company to those who buy or use its products or services, either in person or remotely
  - Design thinking - The set of cognitive, strategic and practical processes by which design concepts are developed
  - User experience - A person’s emotions and attitudes about using a particular product, system or service
  - Value chain - A progression of activities that a business or firm performs in order to deliver goods and services of value to an end customer.
- Tools for Strategy

        - Value proposition canvas - A tool to help you create products and services customers want
        - Persona - A fictional character created to represent a user type relationship
    - Tools for Ideation
        - Affinity diagram - A business tool used to organize ideas and data
        - Brainstorming - A group creativity technique by which efforts are made to find a conclusion for a specific problem by gathering a list of ideas spontaneously contributed by its members
        - SCAMPER - A structured way of assisting students to think out of the box and enhance their knowledge

Metrics & Performance

:::note[Relevant DSS-P Skills]

- 1. Business Transformation > 1.2 Product Management > Design and Operation of Product Performance Metrics
- 1. Business Transformation > 1.1 Strategy Understanding and Architecture Design > Business Value Definition / ROI Estimation and Decision Support

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==== Goal Setting Frameworks

- Goal setting - The process of developing an action plan designed to motivate and guide a person or group toward a goal
    - SMART goals - A mnemonic acronym, used to guide in the setting of objectives or goals, for example in project management, employee-performance management and personal development
        - Specific: Targeting a particular area for improvement
        - Measurable: Quantifying, or at least suggesting, an indicator of progress
        - Assignable: Defining responsibility clearly
        - Realistic: Outlining attainable results with available resources
        - Time-related: Including a timeline for expected results
    - FAST goals - A framework for goals that are Frequently discussed, Ambitious in scope, Specific in metrics, and Transparent for everyone to see
    - GROW model - A simple method for goal setting and problem solving
    - OKRs - A goal-setting framework used by individuals, teams, and organizations to define measurable goals and track their outcomes
    - KPIs - A type of performance measurement used to evaluate the success of an organization or of a particular activity (such as projects, programs, products and other initiatives) in which it engages

- Goodhart’s law - An adage often stated as, "When a measure becomes a target, it ceases to be a good measure"

Performance Measurement

- Net Promoter Score - A market research metric that is based on a single survey question asking respondents to rate the likelihood that they would recommend a company, product, or a service to a friend or colleague
- Rubric - A scoring tool used to evaluate the quality of responses
- SPACE framework - A framework that provides a way to think about developer productivity in a more holistic way, encompassing Satisfaction and well-being, Performance, Activity, Communication and collaboration, and Efficiency and flow
- The Four Keys of DORA - A set of metrics used to measure DevOps performance, consisting of Deployment Frequency, Lead Time for Changes, Change Failure Rate, and Time to Restore Service

Enterprise Strategy & Architecture

:::note[Relevant DSS-P Skills]

- 1. Business Transformation > 1.1 Strategy Understanding and Architecture Design > Understanding of Business Environment and Management Strategy
- 1. Business Transformation > 1.1 Strategy Understanding and Architecture Design > Business and Enterprise Architecture Design
- 1. Business Transformation > 1.3 Management of Transformation Activities > Risk & Compliance

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==== Enterprise Architecture & Administration

- Enterprise architecture - A well-defined practice for conducting enterprise analysis, design, planning, and implementation, using a comprehensive approach at all times, for the successful development and execution of strategy
  - TOGAF standard - A proven Enterprise Architecture methodology and framework used by the world’s leading organizations to improve business efficiency
  - Zachman Framework - An ontology – a theory of the existence of a structured set of essential components of an object
  - ArchiMate - An open and independent modelling language for Enterprise Architecture that is supported by different tool vendors and consulting firms
    - Archi - A free, open source, cross-platform tool and editor to create ArchiMate models
- Enterprise resource planning - The integrated management of main business processes, often in real time and mediated by software and technology

  - Customer relationship management - A strategic process that organizations use to manage, analyze, and improve their interactions with customers
    - EspoCRM - An open-source web application for managing and evaluating all company relationships
    - HubSpot - A customer platform that helps businesses grow by connecting their marketing, sales, and service tools to a shared database
    - Salesforce - A customer relationship management solution that brings companies and customers together, providing one integrated CRM platform for all departments
    - Zendesk - A customer service software and support ticket system that helps businesses build better customer relationships through multi-channel support
    - Atlas - A bespoke AI for customer support that delivers fast, accurate, and measurable support tailored to tools and workflows
    - SuiteCRM - A free and open-source Customer Relationship Management (CRM) software solution providing a 360-degree view of customers and business
  - Supply chain management - The management of the flow of goods and services, between businesses and locations, including the movement and storage of raw materials, work-in-process inventory, and finished goods from point of origin to point of consumption
  - Human resource management - The strategic and coherent approach to the effective and efficient management of of people in a company or organization such that they help their business gain a competitive advantage
    - Competence - The set of demonstrable characteristics and skills that enable and improve the efficiency or performance of a job
  - Contract management - The process of systematically and efficiently managing contract creation, execution, and analysis for the purpose of maximizing financial and operational performance and minimizing risk
  - E-commerce - The activity of electronically buying or selling products on online services or over the Internet
    - Shopify - A Canadian multinational e-commerce company that provides a proprietary e-commerce platform for online stores and retail point-of-sale systems
    - Stripe - A financial infrastructure platform for businesses that provides payment processing software and APIs for e-commerce websites and mobile applications
  - SAP ERP - A comprehensive software system that streamlines processes, improves productivity, and provides real-time insights across your entire organization
  - Odoo - A suite of open source business applications covering areas such as CRM, ERP, accounting, and more
  - ERPNext - A 100% open-source ERP with a modern, comprehensive, and user-friendly enterprise resource planning solution
- Enterprise modeling - The process of building models of whole or part of an enterprise with process models, data models, resource models and or new ontologies

  - BPMN- A graphical notation for specifying business processes in a Business Process Diagram, providing a standard comprehensible to business users yet representing complex process semantics for technical users
  - SysML - A general-purpose graphical modeling language for specifying, analyzing, designing, and verifying complex systems that may include hardware, software, information, personnel, procedures, and facilities
  - Eclipse Capella - A powerful and extensible MBSE software tool that leverages a field-proven language and method to successfully design the architecture of complex systems
- Business process change management
  - Organizational structure - A system that outlines how certain activities are directed in order to achieve the goals of an organization
  - Kotter's 8-step change model - A set of tools and strategies designed to help organizations effectively implement and sustain change
  - Prosci ADKAR Model - A goal-oriented change management model that guides individual and organizational change

Strategic Management

- Strategic management tools
  - MECE principle - The grouping principle for separating a set of items into subsets that are mutually exclusive (ME) and collectively exhaustive (CE)
  - SWOT analysis - A decision-making technique used in strategic planning and management that identifies the strengths, weaknesses, opportunities, and threats of an organization or project
  - PEST analysis - A framework of external macro-environmental factors (political, economic, social and technological) used in strategic management and market research
  - Porter's five forces analysis - A method of analyzing the competitive environment of a business, rooted in industrial organization economics, that identifies five forces determining competitive intensity and industry attractiveness
- Business intelligence and analysis tools
  - Tableau - The visual analytics platform that helps people see, understand, and act on data to solve problems
  - Metabase - The querying and visualization layer for your database, made to fit startup's production DB to massive data warehouses
  - Power BI - A unified, scalable platform for self-service and enterprise business intelligence
    - DAX - A programming language that is used throughout Microsoft Power BI for creating calculated columns, measures, and custom tables

Risk Management

- Risk management - The identification, evaluation, and prioritization of risks followed by coordinated and economical application of resources to minimize, monitor, and control the probability or impact of unfortunate events or to maximize the realization of opportunities
  - Business continuity planning - The process an organization undergoes to create a prevention and recovery system from potential threats such as natural disasters or cyber-attacks
    - IT disaster recovery - The process of resuming normal IT operations after a disruptive event, such as a natural disaster, cyberattack, or equipment failure
    - ISO 22301 (Business continuity management systems) - The international standard for business continuity management systems that specifies requirements to protect against, respond to, and recover from disruptive incidents
  - Project risk management - The process of identifying, analyzing, and then responding to any risk that arises over the life cycle of a project to help the project remain on track and meet its goal
  - Financial risk management - The practice of protecting economic value in a firm by managing exposure to financial risk - principally credit risk and market risk, as well as some aspects of operational risk
  - ISO 31000 (Risk management) - A set of international standards for risk management that provides a consistent vocabulary and methodology for assessing and managing risk

Enterprise AI & Productivity

:::note[Relevant DSS-P Skills]

- 2. Data Preparation & Utilization > 2.1 Strategic Utilization of Data and AI > Data / AI Utilization Strategy Design

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  ==== General Autonomous Agents

- Claude Cowork - An agentic AI system for knowledge work that autonomously plans and executes multi-step tasks across files, documents, and web applications directly on your computer
- OpenClaw - An open-source, self-hosted personal AI agent runtime that acts as a "Local OS for AI" by automating tasks across applications and platforms
- NanoClaw - A lightweight alternative to OpenClaw that runs in containers for security, connects to messaging apps, and runs directly on Anthropic’s Agent SDK
- claw-empire - A local-first AI agent office simulator that orchestrates CLI, OAuth, and API-connected agents as a virtual autonomous company
- Sistava - An AI employee platform for managing teams of AI workers collaborating

through structured sprints, OKRs, and KPIs with persistent memory and real tool access

Enterprise AI Assistants

- Amazon Q Business - A generative AI-powered assistant for enterprises to find information, gain insights, and take action at work, integrating with company data and applications
- Microsoft 365 Copilot - An AI assistant for work that supercharges productivity and creativity, reengineers business processes, and empowers you to securely transform your business into an AI-powered organization
- Notion AI - An integrated AI assistant for workspaces that provides writing assistance, workspace Q&A, and autonomous agents for task automation
- Gemini for Google Workspace - An AI-powered assistant for Docs, Gmail, Sheets, and Slides that helps you write, visualize, and organize your work across the platform
- Claude for Enterprise - A secure and scalable way for organizations to use AI with administrative controls, single sign-on (SSO), and role-based access to Claude's latest models
- ChatGPT Enterprise - An enterprise-grade AI assistant with unlimited higher-speed access to GPT-4, longer context windows, and advanced data analysis capabilities
- Glean - An AI-powered search and assistant for the enterprise that connects to all of your company's apps and data to find exactly what you need

Self-Hosted AI Platforms

- Dify - An open-source LLM app development platform
- OpenWebUI - An extensible, feature-rich, and user-friendly self-hosted AI platform designed to operate entirely offline

AI Agent Registries

- Agent Skills Registries
  - The Agent Skills Directory - An open agent skills ecosystem providing reusable capabilities for AI agents
  - Anthropic Agent Skills - A public repository containing Anthropic's implementation of skills for Claude, including instructions, scripts, and resources that enable specialized tasks and repeatable workflows
  - ClawHub - A community-driven marketplace and platform for discovering and sharing AI agent tools, skills, and plugins, hosting tens of thousands of community-created resources for building AI agents
  - SkillsMP (Skills Management Platform) - A community-driven marketplace designed for discovering and sharing modular AI agent capabilities based on the open SKILL.md standard
  - OpenClaw Skills - The largest open-source registry for community-driven AI tools

designed for platforms like Claude Code and Cursor

- MCP (Model Context Protocol) Registries
  - Official MCP Registry- A collection of official reference MCP server implementations maintained by the Model Context Protocol organization
  - MCP Registry - A searchable web directory of published MCP servers

Human-Centered Design

:::note[Relevant DSS-P Skills]

- 1. Business Transformation > 1.4 Design > Customer / User / Stakeholder Understanding
- 1. Business Transformation > 1.4 Design > Digital Product Design

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==== Core Principles & User Experience (UX)

- Usability - The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use
- User interface design - A craft in which designers perform an important function in creating the user experience
- Accessibility - The design of products, devices, services, or environments for people with disabilities
  - Accessibility Object Model (AOM) - A JavaScript API to allow developers to modify (and eventually explore) the accessibility tree for an HTML page
  - WAI-ARIA - The Accessible Rich Internet Applications suite of web standards
- Prototyping
  - Paper prototyping - A widely used method in the user-centered design process, a process that helps developers to create software that meets the user's expectations and needs
  - Website wireframe - A skeletal outline of a webpage

Cognitive & Behavioral Psychology

- Psychological Models
  - Seven stages of action - An idealized description of the cognitive and physical steps an individual takes to achieve a goal
    - 1: Forming the target.
    - 2: Forming the intention.
    - 3: Specifying an action.
    - 4: Executing the action.

        - 5: Perceiving the state of the world.
        - 6: Interpreting the state of the world.
        - 7: Evaluating the outcome.
- Cognitive Processes
    - Attention - The cognitive process of selectively concentrating on one aspect of the environment while ignoring other things
    - Metacognition - An awareness of one's thought processes and an understanding of the patterns behind them
- Interaction Principles & Laws
    - Principle of least astonishment - A general principle that states that the result of performing some operation should be obvious, consistent, and predictable, based upon the name of the operation and other context
    - Affordance - A property of an object that indicates how it can be used
    - Stroop effect - A demonstration of interference in the reaction time of a task
    - Fitts's law - A predictive model of human movement primarily used in human–computer interaction and ergonomics

Visual Design & Typography

- Typography
    - Typography - The art and technique of arranging type to make written language legible, readable and appealing when displayed
    - Web Typography - The use of fonts on the World Wide Web
    - Microsoft Typography - A comprehensive resource for font technology and typefaces, providing technical specifications, developer tools, and design guidelines for Microsoft products
- Visual Foundations
    - Color space - A specific organization of colors
        - ICC profile - A set of data that characterizes a color input or output device, or a color space
            - sRGB - A standard RGB color space that HP and Microsoft created cooperatively in 1996 for use on monitors, printers, and the Internet
            - HSL and HSV - The two most common cylindrical-coordinate representations of points in an RGB color model
    - Lucide - A beautiful and consistent icon library for various platforms and frameworks
- Font Rendering & Technologies
    - Font Standards
        - TrueType - An outline font standard developed by Apple and Microsoft in the late 1980s as a competitor to Adobe's Type 1 fonts used in PostScript

        - OpenType - A scalable computer font format developed by Microsoft and Adobe as an extension of the TrueType format, supporting advanced typographic features and multi-platform compatibility
        - WOFF (Web Open Font Format) - A font format for use in web pages, developed by Mozilla and others, that provides a compressed wrapper for TrueType and OpenType fonts to improve web performance
        - Variable Fonts - An evolution of the OpenType font specification that enables a single font file to behave like multiple fonts by defining variations in weight, width, and other axes
    - Open Fonts
        - Noto Fonts - A global font collection for all modern and ancient languages
        - Orbitron - A geometric sans-serif typeface intended for display purposes
    - Libraries & Engines
        - FreeType - A freely available software library to render fonts
        - HarfBuzz - A widely used open-source text-shaping engine that converts Unicode text into the glyphs and positions required for proper rendering across various scripts and languages
        - Pango - An open-source library for laying out and rendering of text, with an emphasis on internationalization and support for complex scripts
        - Fontconfig - A library for configuring and customizing font access, used primarily on Linux and other Unix-like systems to provide consistent font matching and substitution
    - Rendering Technologies & APIs
        - ClearType - A subpixel rendering technology developed by Microsoft to improve the readability of text on liquid-crystal displays (LCDs) by utilizing the individual subpixels of each pixel
        - DirectWrite - A high-performance text-layout and font-rendering API from Microsoft that supports hardware-accelerated rendering and high-quality typography for modern applications

Platforms, Frameworks & Guidelines

- Visual Design Tools
    - Claude Design - A visual design tool that lets users collaborate with Claude to create polished designs, prototypes, slides, and marketing materials through natural conversation and iterative refinement
    - Figma Design - A powerful, collaborative design tool for teams
    - Locofy.ai - Design to code in a flash
- Design Systems & Guidelines
    - Material Design - Google’s open-source design system for building beautiful, usable products

    - Apple HIG - A set of recommendations to help you create apps that look and behave consistently across all Apple platforms
    - GNOME HIG - A guide for creating high-quality, consistent, and usable applications for the GNOME desktop

Web Experience & Performance

- Responsive web design - An approach to web design that aims to make web pages render well on a variety of devices and window or screen sizes
- Core Web Vitals - The subset of Web Vitals that apply to all web pages, should be measured by all site owners, and will be surfaced across all Google tools
    - Largest Contentful Paint (LCP)
    - Interaction to Next Paint (INP)
    - Cumulative Layout Shift (CLS)

Systems Thinking: Economics, Game Theory & Finance

:::note[Relevant DSS-P Skills]

- 1. Business Transformation > 1.1 Strategy Understanding and Architecture Design > Understanding of Business Environment and Management Strategy
- 1. Business Transformation > 1.1 Strategy Understanding and Architecture Design > Business Value Definition / ROI Estimation and Decision Support

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==== Economics & Game Theory

- Market - A composition of systems, institutions, procedures, social relations or infrastructures whereby parties engage in exchange
- Inflation - An increase in the general price level of goods and services in an economy over a period of time
- Prospect theory - A theory of behavioral economics and behavioral finance which states that people make decisions based on the potential value of losses and gains rather than the final outcome
- Sunk cost - A cost that has already been incurred and cannot be recovered
- Principal–agent problem - The conflict in priorities between a person or group and the representative authorized to act on their behalf
- Information asymmetry - A situation in which one party in a transaction has more or better information than the other
- Induced demand - The phenomenon that after supply increases, more of a good is consumed
- Metcalfe’s law - The value of a telecommunications network is proportional to the square of the number of connected users of the system (n2)

    - Network effect - The phenomenon by which the value or utility a user derives from a good or service depends on the number of users of compatible products
- Braess's paradox - The observation that adding one or more roads to a road network can slow down overall traffic flow through it
- Nash equilibrium - A solution concept of a non-cooperative game involving two or more players in which each player is assumed to know the equilibrium strategies of the other players, and no player has anything to gain by changing only their own strategy
- Pareto efficiency - A state of allocation of resources from which it is impossible to reallocate so as to make any one individual or preference criterion better off without making at least one individual or preference criterion worse off

Finance & Accounting

- Currency - A standardization of money in any form, in use or circulation as a medium of exchange
- Interest - The payment from a debtor or deposit-taking financial institution to a lender or depositor of an amount above repayment of the principal sum (that is, the amount borrowed), at a particular rate
- Central bank - An institution that manages the monetary policy of a country or monetary union
- Revenue model - A framework for generating financial income
- Financial capital - An economic resource measured in terms of money used by entrepreneurs and businesses to buy what they need to make their products or to provide their services
    - Venture capital - A form of private equity financing that is provided by venture capital firms or funds to startups, early-stage, and emerging companies that have been deemed to have high growth potential
- Markets & Securities
    - Stock market - The aggregation of buyers and sellers of stocks, which represent ownership claims on businesses
    - Stock - Shares that divide ownership of a corporation, representing fractional ownership and typically conferring rights to earnings, liquidation proceeds, or voting power
    - Dividend - The distribution of profits by a corporation to its shareholders from current year profit or retained earnings
- Contracts
    - Credit - The trust which allows one party to provide money or resources to another party wherein the second party does not reimburse the first party immediately
    - Debt - An obligation that requires one party, the debtor, to pay money or otherwise return value to another party, the creditor
        · Discounting - A mechanism in which a debtor obtains the right to delay payments to a creditor, for a defined period of time, in exchange for a charge or fee

        - Bond - A type of security under which the issuer (debtor) owes the holder (creditor) a debt, and is obliged – depending on the terms – to repay the principal of the bond at the maturity date and pay interest over a specified time
    - Spot - A contract of buying or selling a commodity, security or currency for immediate settlement
    - Futures - A standardized legal contract to buy or sell something at a predetermined price for delivery at a specified time in the future
    - Option - A contract which conveys to its owner, the holder, the right, but not the obligation, to buy or sell a specific quantity of an underlying asset or instrument at a specified strike price on or before a specified date
- Cryptocurrency - A type of currency which uses digital files as money
- Accounting Fundamentals
    - Asset - A resource owned or controlled by a business or economic entity that can be used to produce positive economic value
    - Liability - A quantity of value that a financial entity owes and is expected to deliver in the future to satisfy a present obligation arising from past events
    - Equity - An ownership interest in property that may be subject to debts or other liabilities, measured by subtracting liabilities from the value of assets owned
    - Revenue - The total amount of income generated by the sale of goods and services related to the primary operations of a business
    - Depreciation - The decrease in the value of assets and the method used to reallocate the cost of a tangible asset over its useful life span
    - Accrual - An accounting method that recognizes revenues and expenses when they are earned or incurred, not necessarily when cash is received or paid
- Financial Statements & Metrics
    - Balance sheet - A summary of the financial balances of an individual or organization
    - Income statement - One of the financial statements of a company and shows the company’s financial performance for a specific period of time
    - Cash flow statement - A financial statement that shows how changes in balance sheet accounts and income affect cash and cash equivalents
    - Return on investment - The ratio between net income (over a period) and investment (costs resulting from an investment of some resources at a point in time)
    - Net present value - A way of measuring the value of an asset that has cashflow by adding up the present value of all the future cash flows that asset will generate
    - EBITDA - A measure of a company’s profitability of the operating business only, before any effects of indebtedness, state-mandated payments, and costs required to maintain its asset base
    - Operating margin - The ratio of operating income to net sales, usually expressed in percent
    - Burn rate - The rate at which a company consumes its cash, typically expressed

monthly and used for startups to measure how fast a company will use up its shareholder capital

- Liquidity - A market's feature whereby an individual or firm can quickly purchase or sell an asset without causing a drastic change in the asset's price
- Valuation - The process of determining the value of a potential investment, asset, or security

- Accounting Standards & Processes
  - Generally Accepted Accounting Principles - Accounting standards that prescribe in detail what accruals must be made, how financial statements are to be presented, and what additional disclosures are required
  - Audit - An independent examination of financial information of any entity conducted with a view to express an opinion thereon

02 - Web Application Development

Web Platform Fundamentals

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Web Application Core Technology

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  ==== Web Concepts

- World Wide Web - An information space where documents and other web resources are identified by Uniform Resource Locators (URLs), interlinked by hypertext links, and accessible via the Internet
  - Hypertext - A text displayed on a computer display or other electronic devices with references (hyperlinks) to other text that the reader can immediately access
  - Semantic Web - An extension of the World Wide Web that allows Internet data to be machine-readable through standards set by the W3C, enabling automated agents to process information more intelligently
  - URI - A unique sequence of characters that identifies a logical or physical resource
  - URL - A standard that defines URLs, domains, IP addresses, the application/x-www-form-urlencoded format, and their API
- Core Web Protocols & Languages
  - HTTP - An application protocol for distributed, collaborative, hypermedia information systems
    - HTTP cookie - A small piece of data that a server sends to a user's web browser
  - HTML - The World Wide Web's core markup language
  - CSS - A simple mechanism for adding style (e.g., fonts, colors, spacing) to Web documents

- Real-time & Messaging Protocols
  - WebSockets - A technology that makes it possible to open a two-way interactive communication session between the user's browser and a server
  - WebRTC - A free and open-source project providing web browsers and mobile applications with real-time communication (RTC)
  - Server-sent events - A technology to enable servers to push data to web pages over HTTP or using dedicated server-push protocols
  - MQTT - A lightweight, publish-subscribe, machine to machine network protocol for message queue/message queuing service
  - AMQP - An open standard application layer protocol for message-oriented middleware
- Data & Event Specifications
  - CloudEvents - A specification for describing event data in a common way
  - JSON Merge Patch - A JSON format that describes changes to be made to a target JSON document
  - OpenAPI spec - A standard, language-agnostic interface to HTTP APIs
  - TypeSpec - A minimal language that helps developers describe API shapes in a familiar way
  - API Tooling
    - Redocly CLI - An open-source command-line tool that helps you lint, bundle, and preview OpenAPI definitions
- Web Performance Concepts
  - DNS Prefetching - A mechanism to resolve domain names before a user tries to follow a link
- Web Application Types
  - Progressive web app - A type of application software delivered through the web, built using common web technologies including HTML, CSS, JavaScript, and WebAssembly

Browser Technologies & DOM

- Browsers
  - Chrome - A freeware, cross-platform web browser developed by Google
  - Chromium - An open-source browser project that aims to build a safer, faster, and more stable way for all users to experience the web
  - Firefox - A free and open-source web browser developed by the Mozilla Foundation
  - w3m - A text-based web browser as well as a pager
  - EWW - The Emacs Web Wowser, a web browser for Emacs
- Rendering Engines

  - WebKit - The framework for displaying rich, interactive web content in your apps
  - Gecko - The web browser engine developed by Mozilla
  - Blink - The rendering engine used by Chromium
  - Servo - A modern, high-performance browser engine designed for both application and embedded use
- Scripting Engines
  - V8 (JavaScript engine) - Google's open source high-performance JavaScript and WebAssembly engine, written in C++
  - JavaScriptCore - The JavaScript engine that powers Safari and other apps on Apple platforms
- Client Scripting APIs
  - XMLHttpRequest (XHR) - An API that provides scripted client functionality for transferring data between a client and a server
  - Fetch Standard - A living standard that defines requests, responses, and the process that binds them: fetching
  - Canvas API - The means for drawing graphics via JavaScript and the HTML `<canvas>` element
  - WebGL API - A JavaScript API for rendering high-performance interactive 3D and 2D graphics within any compatible web browser without the use of plug-ins
- Site Analyzers
  - Wappalyzer - A technology profiler that shows you what websites are built with

Web Application Architectures

- Single-page application - A web application or website that interacts with the user by dynamically rewriting the current web page with new data from the web server
- Multi-page application - A traditional web structure with multiple pages that are independently downloaded from the server, each having its own URL and loaded separately when requested by the user
- Microfrontend - An architectural pattern for web development where independently developed frontends are composed into a greater whole
- Islands Architecture - A frontend pattern that renders pages to fast, static HTML with selective "islands" of JavaScript added only where interactivity is needed
- Backend for Frontend - An architectural pattern where separate backend services are created specifically for different frontend applications
- Multitier architecture - A client-server architecture where different levels of software architecture are physically separated into presentation, application processing, and data management functions
- Server-side rendering - An approach where static HTML is sent from the server to the client, and client-side JavaScript then makes the web page dynamic by attaching event

handlers in a process called hydration

- Incremental Static Regeneration - A technique that enables static-generation on a per-page basis without needing to rebuild the entire site, allowing updates to static content after deployment
- JAMstack - An architectural approach that decouples the web experience layer from data and business logic, improving flexibility, scalability, performance, and maintainability

Frontend Development

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Front-end System Development
- 1. Business Transformation > 1.4 Design > Digital Product Design

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==== UI Frameworks & Core Libraries

- Core SPA Frameworks
  - React - The library for web and native user interfaces
    - Core Concepts
      - Component - A fundamental building block used to create user interfaces
      - Props - A mechanism for passing data from a parent component to a child component
      - Children - A special prop that allows components to be composed
      - Key Props - A special string attribute you need to include when creating lists of elements
      - Rendering - The process of React asking your components to describe what they want to look like
      - Event Handler - A function that is executed in response to an event
      - State - A JavaScript object that stores a component's dynamic data
      - Controlled Component - A component where React state controls the value of an input element
      - Hooks - A set of functions that let you "hook into" React state and lifecycle features from function components
      - Strict Mode - A tool for highlighting potential problems in an application
      - Side-effect - A term that refers to any operation that affects something outside of the function being executed
      - Refs - A feature that provides a way to access DOM nodes or React elements created in the render method
      - Context - A way to pass data through the component tree without having to pass props down manually at every level

        - Portals - A feature that provides a first-class way to render children into a DOM node that exists outside the DOM hierarchy of the parent component
        - Suspense - A component that lets you specify a loading indicator for a part of the component tree
        - Error Boundary - A React component that catches JavaScript errors anywhere in their child component tree
    - Preact - A fast 3kB alternative to React with the same modern API
    - Vue.js - A JavaScript framework for building user interfaces
    - Angular - A web framework that empowers developers to build fast, reliable applications
    - Svelte - A UI framework that uses a compiler to let you write breathtakingly concise components that do minimal work in the browser, using languages you already know — HTML, CSS and JavaScript
    - Ember.js - A framework for ambitious web developers
- HTML-First Frameworks
    - htmx - A library that allows you to access AJAX, CSS Transitions, WebSockets and Server Sent Events directly in HTML, using attributes
    - htm - A JSX alternative using standard tagged templates, with no transpiler necessary
- Framework-agnostic Core Libraries
    - TanStack - A collection of high-quality, framework-agnostic open-source libraries for web development
        - TanStack Query - A powerful asynchronous state management for TS/JS, React, Solid, Vue, Svelte and Angular
        - TanStack Router - A powerful, type-safe, and framework-agnostic router for building modern web applications
        - TanStack Table - A headless UI for building powerful tables & datagrids for TS/JS, React, Vue, Solid and Svelte
        - TanStack Form - A type-safe and framework-agnostic form state management for React, Vue, Solid, and Svelte
        - TanStack Virtual - A headless UI for virtualizing large lists and grids in React, Vue, Svelte, Solid and JS

State, Routing & Logic

- State Management
    - Redux - A JS library for predictable and maintainable global state management
        - React-Redux - The official React binding for Redux
    - Zustand - A small, fast, and scalable barebones state-management solution using simplified flux principles

    - Recoil - A state management library for React
    - XState - A library for creating, interpreting, and executing finite state machines and statecharts
- Routing
    - React Router - A user-obsessed, standards-focused, multi-strategy router you can deploy anywhere
- Syntax & Templating
    - JSX - A syntax extension for JavaScript that lets you write HTML-like markup inside a JavaScript file
    - MDX - An authorable format that lets you seamlessly write JSX in your Markdown documents
- WASM Runtimes
    - PyScript - A free Open Source Software (OSS) that facilitates the creation, deployment, and sharing of Python applications

Styling & UI Components

- CSS Ecosystem
    - Frameworks and UI Kits
        - Bootstrap - The world's most popular front-end open source toolkit
        - Tailwind CSS - A utility-first CSS framework packed with classes
        - Oat - An ultra-lightweight, semantic, zero-dependency HTML UI component library that provides minimal, standards-based CSS and JS
    - Tailwind Component Libraries
        - daisyUI - The most popular component library for Tailwind CSS
    - CSS-in-JS
        - Emotion - A library designed for writing css styles with JavaScript
        - Linaria - A zero-runtime CSS in JS library
    - Preprocessors
        - Sass language - A stylesheet language that's compiled to CSS
    - Transforms
        - CSS Transforms 1 - A CSS module that allows elements to be transformed in two-dimensional space
        - CSS Transforms 2 - A CSS module that allows elements to be transformed in three-dimensional space
- UI Component Libraries
    - templUI - A growing collection of beautifully designed UI components for Go and templ

    - Material UI - An open-source React component library that implements Google's Material Design
    - Chakra UI - A component system for building products with speed
    - Vuetify - A no design skills required Open Source UI Library with beautifully handcrafted Vue Components
- Specialized UI Widgets
    - Rich Text Editors
        - Tiptap - The headless and open source editor framework designed for web developers
    - Interaction & Media
        - Swiper.js - The most modern mobile touch slider with hardware accelerated transitions and amazing native behavior
        - Hammer.js - A javascript library for multi-touch gestures

Build & Development Tooling

- Development Environments
    - Storybook - A frontend workshop for building UI components and pages in isolation
- Bundlers
    - Vite - A build tool that aims to provide a faster and leaner development experience for modern web projects
    - Parcel - The zero configuration build tool
    - webpack - A static module bundler for modern JavaScript applications
    - Rspack - A high performance JavaScript bundler written in Rust
    - Rsbuild - The Rspack-based web build tool
- Transpilers
    - babel - A JavaScript compiler
- Minifiers
    - JSMin - A minification tool that removes comments and unnecessary whitespace from JavaScript files
- Linters & Formatters
    - Biome - A fast formatter and linter for JavaScript, TypeScript, JSX, TSX, JSON, HTML, CSS and GraphQL that provides a cohesive toolchain for web projects
    - Knip - A tool that finds and fixes unused dependencies, exports and files in JavaScript and TypeScript projects

Full-stack & Static Site Frameworks

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Front-end System Development
- 3. Technology > 3.1 Software Development > Back-end System Development

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==== Full-stack Frameworks

- JS/TS Full-stack Frameworks
  - Next.js - A React framework for building full-stack web applications
  - Nuxt.js - A free and open-source framework with an intuitive and extendable way to create type-safe, performant and production-grade full-stack web applications and websites with Vue.js
  - Astro - The web framework for content-driven websites
  - Fresh - A next generation web framework, built for speed, reliability, and simplicity
- Rust Full-Stack Frameworks
  - Leptos - A cutting-edge Rust framework for the modern web

Static Site Generators

- Docusaurus - A static-site generator. It builds a single-page application with fast client-side navigation, leveraging the full power of React to make your site interactive
- mdBook - A utility to create modern online books from Markdown files
- VuePress - A Vue-powered Static Site Generator
- Hugo - The world's fastest framework for building websites
  - Docsy - A Hugo theme for technical documentation sites, providing easy site navigation, structure, and more
- Jekyll - A simple, blog-aware, static site generator perfect for personal, project, or organization sites
- Eleventy - A simpler static site generator written in JavaScript
- Sphinx - A tool that makes it easy to create intelligent and beautiful documentation
- MkDocs - A fast, simple and downright gorgeous static site generator that's geared towards building project documentation
  - Material for MkDocs - A powerful and beautiful theme for the MkDocs static site generator
- Nanoc - A static-site generator, fit for building anything from a small personal blog to a large corporate website
- gitmal - A static page generator designed for Git repositories

Headless CMS

- Cloud-native & API-first CMS

  - Contentful - A headless content management system that provides a content-first approach to building digital products
  - Strapi - The leading open-source headless CMS
  - Sanity - A platform for structured content that lets you build better digital experiences

Backend Development

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Back-end System Development

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  ==== API Architectural Styles

- REST - A software architectural style that was created to guide the design and development of the architecture for the World Wide Web
- SOAP (legacy) - A messaging protocol specification for exchanging structured information in the implementation of web services
- GraphQL - A query language for APIs and a runtime for fulfilling those queries with your existing data
- gRPC - A modern open source high performance Remote Procedure Call (RPC) framework that can run in any environment
- json-rpc - A stateless, light-weight remote procedure call (RPC) protocol
- Webhook - A method of augmenting or altering the behavior of a web page or web application with custom callbacks

Backend Frameworks

- JS/TS Backend Frameworks
  - Fastify - A fast and low-overhead web framework for Node.js, designed for optimal performance and developer experience
  - Express.js - A minimal and flexible Node.js web application framework
  - Koa - A new web framework designed by the team behind Express
  - Nest.js - A progressive Node.js framework for building efficient, reliable and scalable server-side applications
  - Hono - A small, simple, and ultrafast web framework for the Edges
- API Tools
  - tRPC - A tool that allows you to easily build & consume fully typesafe APIs without schemas or code generation
- Go Backend Frameworks
  - Echo - A high performance, extensible, minimalist Go web framework

    - Fiber - An Express inspired web framework built on top of Fasthttp, the fastest HTTP engine for Go, designed to ease development with performance in mind
    - Gin Web Framework - A web framework written in Go
    - Gorilla web toolkit - A helpful toolkit that provides useful, composable packages for writing HTTP-based applications
    - Yokai - A simple, modular and observable Go framework for backend applications
- Python Backend Frameworks & Servers
    - WSGI - The Web Server Gateway Interface
        - Gunicorn - A Python WSGI HTTP Server for UNIX
        - Flask - A lightweight WSGI web application framework
    - ASGI - A spiritual successor to WSGI, the long-standing Python standard for compatibility between web servers, frameworks, and applications
        - Uvicorn - A lightning-fast ASGI server implementation for Python, using uvloop and httptools for high performance
        - Hypercorn - An ASGI and WSGI web server based on the sans-io hyper, h11, h2, and wsproto libraries with support for HTTP/1, HTTP/2, and HTTP/3
        - FastAPI - A modern, fast (high-performance), web framework for building APIs with Python based on standard Python type hints
        - SlowAPI - A small library to rate limit your ASGI applications
- Ruby Backend Frameworks & Servers
    - Ruby on Rails - A web-application framework that includes everything needed to create database-backed web applications according to the Model-View-Controller (MVC) pattern
    - Rack - A modular Ruby web server interface
        - Puma - A fast, concurrent web server for Ruby & Rack
        - Falcon - A multi-process, multi-fiber rack-compatible HTTP server built on top of async, async-container and async-http
        - Sinatra - A DSL for quickly creating web applications in Ruby with minimal effort
    - Sidekiq - A simple, efficient background processing tool for Ruby
- Perl Backend Frameworks (legacy)
    - Classic CGI
        - mod_cgi - A module for the execution of CGI scripts
        - CGI.pm - A module to handle Common Gateway Interface requests and responses
    - Fast CGI
        - mod_fcgid - A high performance alternative to mod_cgi or mod_cgid
        - FCGI.pm - A module for FastCGI applications

- Java Backend Frameworks
  - Jakarta EE - A set of specifications that define Java APIs for enterprise software development
    - Apache Tomcat - An open-source web server and servlet container
  - Spring - A project that makes Java simple, modern, productive, reactive, and cloud-ready
    - Spring Boot - A tool that takes an opinionated view of the Spring platform and third-party libraries so you can get started with minimum fuss
- .NET Backend Frameworks
  - ASP.NET - A free, cross-platform, open source framework for building web apps and services with .NET and C#
- Elixir Backend Frameworks
  - Phoenix - A web framework for building rich, interactive web applications quickly with less code and fewer moving parts, used to craft APIs, HTML5 apps, and more at scale
- GraphQL Servers
  - Apollo Server - An open-source, spec-compliant GraphQL server that's compatible with any GraphQL client

Web Infrastructure

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Cloud Infrastructure Utilization

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  ==== Web Server & Proxy

- Web Servers & Reverse Proxy Servers
  - NGINX - An open source software for web serving, reverse proxying, caching, load balancing, media streaming, and more
  - Apache HTTP Server - A project to develop and maintain an open-source HTTP server for modern operating systems including UNIX and Windows
  - Caddy - A powerful, extensible platform to serve your sites, services, and apps, written in Go
  - HAProxy - A free, very fast and reliable reverse-proxy offering high availability, load balancing, and proxying for TCP and HTTP-based applications
  - nodejs http-server - A simple static HTTP server
  - goshs - A feature-rich single-binary file server for red teamers and developers supporting HTTP/S, WebDAV, SFTP, SMB, LDAP/S, NTLM hash capture, DNS/SMTP callbacks, TLS, authentication, and share links

- API Management
  - Unkey - An open-source API management platform designed to help developers secure, manage, and scale their APIs
  - Kong API gateway - A lightweight, fast, and flexible cloud-native API gateway
  - Azure API Management - A hybrid, multicloud management platform for APIs across all environments
  - Amazon API Gateway - A fully managed service that makes it easy for developers to create, publish, maintain, monitor, and secure APIs at any scale
  - Google Cloud Apigee - The platform for developing and managing API services
  - Gravitee - A unified API visibility and governance platform that provides a single pane of glass for managing, securing, and governing APIs across any infrastructure

CDN & Edge Computing

- Concepts
  - Web cache - An information technology for the temporary storage (caching) of web documents, such as HTML pages and images, to reduce bandwidth usage, server load, and perceived lag
  - Content delivery network - A geographically distributed network of proxy servers and their data centers
    - Point of presence - An artificial demarcation point or interface point between communicating entities
- Forward Proxy Servers
  - Squid - A caching proxy for the Web supporting HTTP, HTTPS, FTP, and more
- CDN Providers
  - Cloudflare - A global network designed to make everything you connect to the Internet secure, private, fast, and reliable
    - Cloudflare Workers - A serverless execution environment that allows you to create entirely new applications or augment existing ones without configuring or maintaining infrastructure
    - Cloudflare Workers Bindings - A mechanism that allows your Worker to interact with resources on the Cloudflare Developer Platform, providing better performance and fewer restrictions than REST APIs for accessing resources from Workers
  - Amazon CloudFront - A content delivery network (CDN) service built for high performance, security, and developer convenience
    - Lambda@Edge - A feature of Amazon CloudFront that lets you run code closer to users of your application
  - Google Cloud CDN - A content delivery network (CDN) that accelerates delivery of your web and video content

  - Azure Front Door - A modern cloud content delivery network (CDN) that provides a secure and scalable entry point for fast delivery of your global web applications and content

- JAMstack Hosting
  - GitLab Pages - A feature that allows you to publish static websites directly from a repository in GitLab
  - Cloudflare Pages - A JAMstack platform for frontend developers to collaborate and deploy websites

Decentralized Web

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.2 Digital Technology > Other Advanced Technologies

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  ==== Blockchain Technology

- Web3 - An idea for a new iteration of the World Wide Web which incorporates concepts such as decentralization, blockchain technologies, and token-based economics
- Blockchain - A distributed ledger with growing lists of records
  - Hashcash - A proof-of-work system used to limit email spam and denial-of-service attacks
  - Proof of work - A form of cryptographic proof in which one party proves to others that a certain amount of a specific computational effort has been expended
- Smart contract - A computer program or transaction protocol designed to automatically execute, control, or document events and actions according to contract terms
- Bitcoin - A decentralized digital currency that can be transferred on the peer-to-peer bitcoin network
- Ethereum - A global, decentralized network that provides direct ownership of digital assets, data, and identity without requiring permission from any central authority
- Non-fungible token - A unique digital identifier that is recorded on a blockchain and is used to certify ownership and authenticity
- Decentralized autonomous organization - A member-owned community without centralized leadership managed by decentralized computer programs with voting and finances handled through a blockchain
- Solidity - A programming language for implementing smart contracts on various blockchain platforms, most notably Ethereum
- Web3.js - A TypeScript/JavaScript library that enables developers to connect to and interact with Ethereum and other EVM-compatible blockchains
- ethers.js - A simple, compact and complete JavaScript library for all your Ethereum needs

- MetaMask - A crypto wallet that enables users to buy, sell, swap, and store cryptocurrencies while maintaining control over their data and assets
- WalletConnect - An open-source protocol that establishes encrypted connections between mobile cryptocurrency wallets and desktop-based decentralized applications
- Hardhat - A development environment for Ethereum and EVM-compatible blockchains that helps developers compile, deploy, test, and debug Solidity smart contracts

Decentralized Social

- ActivityPub - A decentralized social networking protocol based on the ActivityStreams 2.0 data format
- AT Protocol - An open data network for building social applications where users own their identities and content is represented as interlinked JSON records
- Fediverse - An ensemble of interconnected servers that are used for web publishing and file hosting, but which can communicate with each other
- Mastodon - A free, open-source, decentralized social media platform that puts users in control of their feeds without algorithms or ads, allowing independent servers to interoperate through the ActivityPub protocol
- Bluesky - A microblogging social media service and a public benefit corporation based in the United States
- Nostr - An open, decentralized social protocol that uses cryptographic signatures to enable censorship-resistant communication across multiple independent servers called relays
- Matrix - An open standard and communication protocol for real-time communication that enables seamless communication between different service providers
- PeerTube - A free, open-source tool for creating independent video hosting platforms that connect to form a decentralized network, offering an alternative to centralized services
- Lemmy - A decentralized discussion platform that allows users to control their experience without corporate tracking or advertising
- Diaspora - A nonprofit, user-owned, distributed social network consisting of independently owned nodes called pods that interoperate to form the network
- Secure Scuttlebutt - A decentralized social network platform that enables local community development free from corporate data harvesting

Development & Testing Tools

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Computer Science
- 3. Technology > 3.1 Software Development > Team Development

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==== Web/HTTP Clients

- HTTP CLI Tools
  - cURL - A command line tool and library for transferring data with URLs
  - Wget - A free software package for retrieving files using HTTP, HTTPS, FTP and FTPS
  - curlie - The power of curl, the ease of use of httpie
  - hurl - A command line tool that runs HTTP requests defined in a simple plain text format
  - httpie cli - A simple yet powerful command-line HTTP and API testing client for the API era
  - wuzz - An interactive CLI tool for HTTP inspection
  - httptap - A tool to view the HTTP and HTTPS requests made by any Linux program
- HTTP Client Libraries
  - Python Requests - An elegant and simple HTTP library for Python, built for human beings
  - JS Axios - A promise-based HTTP Client for node.js and the browser
  - Go Resty - A simple HTTP and REST client library for Go
  - Go FastHTTP - A fast HTTP package for Go
  - Surf - An advanced Go HTTP client with Chrome/Firefox browser impersonation, HTTP/3 with QUIC fingerprinting, JA3/JA4 TLS emulation, and anti-bot bypass
  - Typhoeus - A library that wraps libcurl in order to make fast and reliable requests
  - Ruby Net - A collection of classes that implement client-side internet protocols
  - httpx - An HTTP client library for the Ruby programming language
  - wreq-ruby - An easy and powerful Ruby HTTP client with advanced browser fingerprinting that accurately emulates various browsers with precise TLS/HTTP2 signatures
  - Rust reqwest - An ergonomic, async HTTP client
- GraphQL Libraries
  - URQL - The highly customizable and versatile GraphQL client for React, Svelte, Vue, or plain JavaScript
- API Testing Platforms
  - Bruno - A Git-integrated, fully offline, and open-source API client
  - Postman/Newman - An API platform for building and using APIs
- Classic Web Automation
  - Mechanize - A module that helps you automate interaction with a website
  - Mechanize (Ruby) - A ruby library that makes automated web interaction easy

Web Debugging Tools

- Chrome DevTools - A set of web developer tools built directly into the Google Chrome browser
- Firefox Developer Tools - A set of web developer tools built into Firefox that allow you to examine, edit, and debug HTML, CSS, and JavaScript
- React Developer Tools - A browser extension and standalone debugger that allows developers to inspect React components, edit props and state, and identify performance problems in React applications
- Vue.js devtools - A browser extension for debugging Vue.js applications that provides component inspection and state management debugging
- Redux DevTools - A development tool that provides power-ups for Redux development workflow, including hot reloading, action replay, and customizable UI
- Lighthouse - An open-source, automated tool that helps improve web page quality by auditing performance, accessibility, SEO, and best practices
- Fiddler - A free web debugging proxy for any browser, system or platform
- Charles Proxy - An HTTP proxy/monitor that enables developers to view all HTTP and SSL/HTTPS traffic between their machine and the Internet, including requests, responses, and headers
- mitmproxy - A free and open source interactive HTTPS proxy that can intercept, inspect, modify, and replay web traffic for debugging, testing, and penetration testing purposes
- Requestly - An HTTP interceptor that allows developers to modify URLs, headers, and API responses in real-time for debugging and testing

Web Test Automation Frameworks

- Browser Automation & Testing
  - Puppeteer - A Node.js library which provides a high-level API to control Chrome/Chromium over the DevTools Protocol
  - Playwright - A framework for reliable end-to-end testing for modern web apps with a single API for Chromium, Firefox, and WebKit
    - Playwright for Go - A Go library to automate Chromium, Firefox and WebKit with a single API
  - Cypress - An open-source, JavaScript-based testing framework that enables developers to write, run, and debug end-to-end and component tests directly in the browser for modern web applications
  - WebDriver - A remote control interface that enables introspection and control of user agents
    - Selenium WebDriver - A tool that drives a browser natively, as a user would, either locally or on a remote machine
    - WebDriver BiDi - The BiDirectional WebDriver Protocol, a mechanism for remote control of user agents

    - Selenium IDE - An open source record and playback test automation for the web
    - Chrome DevTools Protocol (CDP) - A low-level API that allows external tools to instrument, inspect, debug, and profile Chromium-based browsers
    - Karma - A test runner that spawns a web server and executes source code against test code for each of the connected browsers
    - Supporting Tools
        · Chrome for Testing - A new flavor of Chrome that specifically targets web app testing and automation use cases
- Accessibility Testing
    - axe-core - An accessibility testing engine for websites and other HTML-based user interfaces
- AI-powered Web Automation
    - browser-use - An open-source Python library that allows AI agents to interact with web browsers using natural language
- Web Scraping
    - Crawlee - A web scraping and browser automation library
    - BeautifulSoup - A Python library designed for quick turnaround projects like screen-scraping
    - Scrapy - An open source and collaborative framework for extracting the data you need from websites
    - Colly - A Golang framework for building web scrapers
    - Katana - A next-generation crawling and spidering framework
    - Trafilatura - A Python package and command-line tool to gather text on the Web

03 - Cloud & Cloud-Native Computing

Cloud Computing

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Cloud Infrastructure Utilization

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  ==== Computing & Storage (IaaS)

- Amazon EC2 - A web service that provides secure, resizable compute capacity in the cloud
- Amazon EBS - An easy-to-use, high-performance block storage service designed for use with Amazon Elastic Compute Cloud
- Azure Virtual Machines - A service to provision Windows and Linux virtual machines in seconds

- Azure Disk Storage - A high-performance, durable block storage for Azure Virtual Machines
- Google Cloud Compute Engine - A customizable compute service that lets you create and run virtual machines on Google's infrastructure

Networking

- Amazon VPC - A service that lets you launch AWS resources in a logically isolated virtual network that you define
- Amazon ELB - A service that automatically distributes incoming application traffic across multiple targets, such as Amazon EC2 instances, containers, IP addresses, and Lambda functions
- Azure Virtual Network - The fundamental building block for your private network in Azure with access to high-performance networking
- Azure Load Balancer - A service that allows you to distribute traffic to your backend virtual machines
- Azure Application Gateway - A platform-managed, scalable, and highly available application delivery controller as a service
- Google Cloud VPC - A virtual version of a physical network that is implemented inside of Google's production network by using Andromeda
- Cloud Load Balancing - A fully distributed, software-defined, managed service for all your traffic

Application Hosting Platform (PaaS)

- Azure App Service - An HTTP-based service for hosting web applications, REST APIs, and mobile back ends
- AWS Elastic Beanstalk - An easy-to-use service for deploying and scaling web applications and services
- Google Cloud App Engine - A fully managed, serverless platform for developing and hosting web applications at scale
- Vercel - A frontend cloud platform that provides the developer experience and infrastructure to build, deploy, and scale the web
- Netlify - A composable web platform that enables enterprises and teams to build, deploy, and scale modern web experiences on a global edge network
- Coolify - An open-source & self-hostable alternative to Vercel, Heroku, Netlify and Railway

Cloud Command Line Interfaces

- AWS CLI - A unified tool to manage your AWS services
- Azure CLI - A cross-platform command-line tool for managing Azure resources with interactive commands or scripts

- Azure Developer CLI (azd) - An open-source tool that accelerates your path from a local development environment to Azure
- Google Cloud CLI (gcloud) - A set of tools to create and manage Google Cloud resources and services
- Vercel CLI - A command-line interface used to manage and configure Vercel Projects, deploy apps, and replicate the deployment environment locally
- Netlify CLI - A command-line interface to configure continuous deployment, run a local development server, and deploy sites on Netlify

Cloud Emulators

- LocalStack - A fully functional local cloud stack to develop and test your cloud and serverless apps offline

Private Cloud & On-Premises IaaS

- OpenStack - An open source cloud computing platform that provides infrastructure as a service (IaaS) for building and managing public and private clouds
- OpenNebula - The Enterprise Cloud and Virtualization Platform that delivers end-to-end coverage, vendor neutrality, and comprehensive support across cloud and virtualization management, hypervisor operations, and Kubernetes orchestration

Cloud Architecture Frameworks

- AWS Well-Architected Framework - A framework describing key concepts, design principles, and architectural best practices for designing and running workloads in the cloud
- Azure Architecture Center - A set of guidance, patterns, and best practices for building secure, high-performing, resilient, and efficient infrastructure on Azure
- Azure Well-Architected Framework - A set of quality-driven tenets, architectural decision points, and review tools intended to help solution architects build a technical foundation for their workloads

Configuration as Code

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Cloud Infrastructure Utilization

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  ==== Infrastructure as Code (IaC)

- Hashicorp Terraform - An infrastructure as code tool that lets you build, change, and version infrastructure safely and efficiently
- OpenTofu - An open-source, community-driven fork of Terraform that provides a stable,

drop-in replacement for building and managing infrastructure

- Pulumi - An infrastructure as code platform that allows you to use familiar programming languages and tools to build, deploy, and manage cloud infrastructure

AI-driven Infrastructure

- Spacelift Intent - An AI-powered tool that allows users to provision and manage cloud infrastructure using natural language

Configuration Management & Automation

- Ansible - An open source IT automation engine that automates provisioning, configuration management, application deployment, orchestration, and many other IT processes
- SaltStack - A Python-based, open-source software for event-driven IT automation, remote task execution, and configuration management
- Rudder - An open-source, continuous configuration and compliance platform for IT infrastructure automation
- cloud-init - The standard for customising cloud instances

Image Building

- Hashicorp Packer - A tool for creating identical machine images for multiple platforms from a single source configuration

Ecosystem & Vendor Tools

- Terraform/OpenTofu Ecosystem
  - Terraform/OpenTofu Provider: Core Functions - A Terraform/OpenTofu provider for performing core functions
  - Terragrunt - A thin wrapper that provides extra tools for keeping your configurations DRY, working with multiple Terraform modules, and managing remote state
  - TerraTest - A Go library that provides patterns and helper functions for testing infrastructure
  - Atmos - A universal tool for DevOps and Cloud Engineering that orchestrates workflows and simplifies the management of infrastructure
  - GitLab-managed Terraform/OpenTofu state - A feature that allows you to store your Terraform state files in GitLab
  - tf.libsonnet - A collection of Jsonnet libraries for generating Terraform code
  - terraform-docs - A utility to generate documentation from Terraform modules in various output formats
  - Terraformer - A CLI tool to generate terraform files from existing infrastructure

    - Atlantis - A self-hosted golang application that listens for Terraform pull request events via webhooks
- Vendor-specific Tools
    - AWS CloudFormation - A service that helps you model and set up your Amazon Web Services resources
    - AWS CDK - An open source software development framework to define your cloud application resources using familiar programming languages
    - AWS SAM - An open-source framework for building serverless applications
    - SST - A framework that makes it easy to build full-stack applications on AWS with a specialized focus on serverless and event-driven architectures
    - Azure Resource Manager - The deployment and management service for Azure
        · Bicep language - A domain-specific language (DSL) that uses declarative syntax to deploy Azure resources
        · Azure Resource Graph - A powerful management tool to query, explore, and analyze your cloud resources at scale

Containerization

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Cloud Infrastructure Utilization

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- Containerization - A form of operating-system-level virtualization
- Linux Distros for Containers
    - Alpine Linux - A security-oriented, lightweight Linux distribution based on musl libc and busybox
        · apk-tools - A package manager originally built for Alpine Linux
    - Fedora CoreOS - An automatically updating, minimal operating system for running containerized workloads securely and at scale
    - Flatcar Container Linux - An immutable Linux distribution for containers
- Utilities in Containers
    - busybox - A single small executable that combines tiny versions of many common UNIX utilities
- Standards
    - The Open Container Initiative (OCI) - An open governance structure for the express purpose of creating open industry standards around container formats and runtimes
    - Compose Specification - A developer-focused standard for defining cloud and platform agnostic container-based applications
    - Development Containers - An open specification for enriching containers with development-specific settings, tools, and configuration

Engines & Runtimes

- Container Engines
  - Docker Engine - An open source containerization technology for building and containerizing your applications
    - Docker Rootless mode - A feature that allows the Docker daemon and containers to run as a non-root user, mitigating potential vulnerabilities
  - podman - A powerful container engine for building, managing, and running containers and pods
    - podman-static - Alpine-based container images and statically linked (rootless) binaries for Linux
- Container Runtimes
  - containerd - An industry-standard container runtime with an emphasis on simplicity, robustness and portability
    - nerdctl - A Docker-compatible CLI for containerd
    - ctr - An unsupported debug and administrative client for interacting with the containerd daemon
  - CRI-O - An implementation of the Kubernetes CRI (Container Runtime Interface) to enable using OCI (Open Container Initiative) compatible runtimes
    - cri-tools - A set of tools for CRI
- OCI Runtimes
  - runc - A CLI tool for spawning and running containers according to the OCI specification
  - crun - A fast and lightweight fully featured OCI runtime and C library for running containers

Image Management

- Image Building Tools
  - Docker Build - A part of the Docker Engine that automates the process of creating a Docker image from a Dockerfile and a context
  - buildah - A tool that facilitates building Open Container Initiative (OCI) container images
  - podman build - A command that constructs OCI-compatible container images by interpreting instructions from a Containerfile or Dockerfile, leveraging Buildah for the underlying operations
  - Kaniko - A tool to build container images from a Dockerfile, inside a container or Kubernetes cluster
- Image Inspection & Management Tools
  - skopeo - A command line utility that performs various operations on container images

and image repositories

  - dive - A tool for exploring a docker image, layer contents, and discovering ways to shrink the size of your Docker/OCI image
  - regclient - A suite of command-line tools (regctl, regsync, regbot) for managing and inspecting OCI registries and images, supporting advanced features like multi-platform images and mirroring

- Container Registries
  - GitLab Container Registry - A secure and private registry for Docker images
  - Project Quay - An open-source, container-native image registry designed for building, organizing, distributing, and deploying containers
  - Docker Hub - A cloud-based registry service that allows developers and teams to store, share, and distribute Docker container images
  - Amazon ECR - A fully managed container registry that makes it easy to store, manage, share, and deploy your container images and artifacts
  - Azure Container Registry - A private registry for managing container images and related artifacts
  - Harbor - An open source registry that secures artifacts with policies and role-based access control

Environment & Management

- Container Management Tools
  - Podman Desktop - The best free and open source tool for developers to work with containers and Kubernetes, simplifying container management, streamlining Kubernetes workflows, and transitioning from local development to production with ease
  - lazydocker - A terminal UI for both docker and docker-compose
  - Docker Compose - A tool for defining and running multi-container Docker applications
- Development Environment Provisioning
  - devcontainers CLI - A reference implementation for the specification that can create and configure a dev container from a devcontainer.json, providing commands for building, running, and managing development containers across different infrastructures
  - DevPod - A client-only tool that enables dev-environments-as-code using the open standard devcontainer.json format, supporting any infrastructure including local machines, Kubernetes clusters, and cloud providers
- Local Environment Provisioners (for Mac)
  - Colima - A tool that provides container runtimes on macOS (and Linux) with minimal setup
  - Lima - A tool that launches Linux virtual machines with automatic file sharing and port forwarding

WebAssembly

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.2 Digital Technology > Other Advanced Technologies

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- Standards
  - WebAssembly - A binary instruction format for a stack-based virtual machine
  - WebAssembly System Interface (WASI) - A modular system interface for WebAssembly
  - WASIX - The long term stabilization and support of the existing WASI ABI plus additional non-invasive syscall extensions
  - WebAssembly Component Model - A binary interface standard letting modules interoperate through typed, language-agnostic interfaces, developed as part of WASI Preview 2
- Runtimes
  - wazero - The only zero dependency WebAssembly runtime written in Go
  - Wasmtime - A fast and secure runtime for WebAssembly
  - Wasmer - A blazing fast and secure WebAssembly runtime that enables incredibly lightweight containers to run anywhere
  - WasmEdge - A lightweight, high-performance, and extensible runtime for cloud native, edge, and decentralized applications
  - WebAssembly Micro Runtime (WAMR) - A lightweight standalone runtime with small footprint and highly configurable features for embedded, IoT, edge, and Trusted Execution Environment use
- Toolchains & Languages
  - Emscripten - A complete compiler toolchain to WebAssembly, using LLVM, with a special focus on speed, size, and the Web platform
  - AssemblyScript - A TypeScript-like language for WebAssembly
  - TinyGo - A Go compiler for small places, bringing the language to embedded systems and WebAssembly
  - Binaryen - A compiler and toolchain infrastructure library for WebAssembly, written in C++
- Cloud & Edge Platforms
  - wasmCloud - An open source CNCF project to build polyglot applications composed of reusable WebAssembly components across cloud, Kubernetes, and edge
  - Fermyon Spin - The developer tool for building WebAssembly microservices and web applications

Kubernetes

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Cloud Infrastructure Utilization

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- Kubernetes - An open-source system for automating deployment, scaling, and management of containerized applications
- Master node
  - kube-apiserver - Responsible for API services
  - kube-scheduler - Responsible for scheduling
  - kube-controller-manager - Responsible for container orchestration
- Compute node
  - kubelet - watches the API server for pods on that node and makes sure they are running
  - cAdvisor - collects metrics about pods running on that particular node
  - kube-proxy - watches the API server for pods/services changes in order to maintain the network up to date
  - container runtime - responsible for managing container images and running containers on that node
- Interface Standards
  - CNI (Container Networking Interface)
  - CSI (Container Storage Interface)
  - CRI (Container Runtime Interface)

Core Concepts & Components

- K8s Internals
  - Workloads - The objects you use to manage and run your containers on the cluster
  - Pod
    - assignment - The process of constraining a Pod so that it is restricted to run on particular nodes, or to prefer to run on particular nodes
    - taint and toleration - A mechanism that allows you to ensure that pods are not placed on inappropriate nodes
    - lifecycle - The lifecycle of a Pod
    - liveness probe - A probe the kubelet uses to know when to restart a container
    - requests and limits
    - eviction

    - Deployment, ReplicaSet, StatefulSet, DaemonSet
    - Kubernetes network model - A set of fundamental requirements and principles for networking in a Kubernetes cluster
        - Service, Ingress, Ingress Controllers
    - Storage - A powerful volume subsystem with an API that abstracts how storage is provided and consumed
        - PersistentVolume, PVC, StorageClass
    - Configuration - A range of mechanisms that let you inject configuration data into the Pods that run your applications
        - Secret, ConfigMap
    - Security & Policy
        - Kubernetes RBAC - A method of regulating access to computer or network resources based on the roles of individual users within an enterprise
        - PodDisruptionBudget - An object that limits the number of concurrent disruptions that your application experiences, allowing for high availability
        - Security context - A definition of privilege and access control settings for a Pod or Container
- Autoscaling
    - HPA - The component that automatically scales the number of Pods in a replication controller, deployment, replica set or stateful set based on observed CPU utilization
    - Cluster Autoscaler - A tool that automatically adjusts the size of the Kubernetes cluster
    - Karpenter - A flexible, high-performance Kubernetes cluster autoscaler

Operations & Management

- K8s Operators
    - Prometheus Operator - The operator that creates/configures/manages Prometheus clusters atop Kubernetes
        - kube-prometheus - A collection of Kubernetes manifests, Grafana dashboards, and Prometheus rules combined with documentation and scripts to provide easy to operate end-to-end Kubernetes cluster monitoring
    - OpenTelemetry Operator - An implementation of a Kubernetes Operator for OpenTelemetry
    - Elastic Cloud on Kubernetes (ECK) - The official operator for the Elastic Stack on Kubernetes
    - Rook - An open source cloud-native storage orchestrator for Kubernetes
- Dashboards
    - k9s - A terminal based UI to interact with your Kubernetes cluster

  - KDash - A simple terminal dashboard for Kubernetes built with Rust
  - Seabird - The native desktop app that simplifies working with Kubernetes
  - Headlamp - A user-friendly Kubernetes UI focused on extensibility

CLI & Local Environments

- CLI Plugin Management
  - Krew - The plugin manager for kubectl command-line tool
    - kubectl-node-shell - A kubectl plugin to run a root shell on a node
    - kubectl-tree - A kubectl plugin to explore ownership relationships between Kubernetes objects
    - kubectl-pod-inspect - A kubectl plugin to view pod and container status at a glance
    - kubepug - A pre-flight checking tool for Kubernetes APIs
    - rakkess - A kubectl plugin to show an access matrix for all available resources
    - ketall - A kubectl plugin to get all resources
- Local K8s Tools
  - Minikube - A tool that lets you run Kubernetes locally
  - Kind - A tool for running local Kubernetes clusters using Docker container “nodes”

Ecosystem & Extensions

- Application Packaging & Configuration
  - Helm - The package manager for Kubernetes
  - Kustomize - A standalone tool to customize Kubernetes objects through a kustomization file
  - Artifact Hub - A web-based application designed to facilitate the finding, installing, and publishing of Cloud Native packages and configurations
- Cloud Resource Management
  - Crossplane - A cloud-native framework for platform engineering that enables users to build their own APIs and services with control planes, extending Kubernetes to manage any resource anywhere
- Developer Workflow Tools
  - Skaffold - A command line tool that facilitates continuous development for container-based applications
- Platform Extensions
  - kube-fencing - A solution for fencing of stateful application’s nodes in Kubernetes
  - KubeVirt - A virtual machine management add-on for Kubernetes

- Operator & Controller Development
  - Kubebuilder - A framework for building Kubernetes APIs using custom resource definitions (CRDs)
- Resource Optimization
  - Goldilocks - A utility that can help you identify a starting point for resource requests and limits
- Vendor-specific Tools
  - eksctl - The official CLI for Amazon EKS

Cloud-Native Computing

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Cloud Infrastructure Utilization

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- Serverless Computing - A cloud computing execution model in which the cloud provider allocates machine resources on demand, taking care of the servers on behalf of their customers

Container as a Service (CaaS)

- Managed Kubernetes
  - Google Kubernetes Engine (GKE) - A managed, production-ready environment for running containerized applications
  - Amazon Elastic Kubernetes Service - A managed service that makes it easy to run Kubernetes on AWS and on-premises
  - Azure Kubernetes Service (AKS) - A fully managed Kubernetes service for deploying and managing containerized applications
- Simplified Container Hosting
  - Amazon Elastic Container Service - A fully managed container orchestration service that helps you easily deploy, manage, and scale containerized applications
  - AWS Fargate - A serverless compute engine for containers that works with both ECS and EKS
  - AWS App Runner - A fully managed service that makes it easy for developers to quickly deploy containerized web applications and APIs, at scale and with no prior infrastructure experience required
  - Azure Container Apps - A fully managed serverless container service built on Kubernetes, integrating KEDA, Dapr, and Envoy for microservices and event-driven workloads
  - Google Cloud Run - A managed compute platform that lets you run containers that are automatically scaled

Function as a Service (FaaS)

- AWS Lambda - A serverless, event-driven compute service that lets you run code for virtually any type of application or backend service without provisioning or managing servers
- Azure Functions - An event-driven, serverless compute platform that helps you develop more efficiently using the programming language of your choice
- Google Cloud Run Functions - A serverless execution environment for building and connecting cloud services

Advanced Runtimes & Isolation

- Sandboxed Runtimes
  - Kata Containers - An open-source project building a standard implementation of lightweight virtual machines that feel and perform like containers, but provide the workload isolation and security of virtual machines
  - gVisor - A Linux-compatible sandbox that implements the Linux kernel and its network stack, intercepting system calls to protect the host from containerized applications
  - libkrun - A dynamic library providing virtualization-based process isolation capabilities
  - Cloud Hypervisor - An open source Virtual Machine Monitor (VMM) implemented in Rust that focuses on running modern, cloud workloads, with minimal hardware emulation
  - Firecracker - An open source virtualization technology that is purpose-built for creating and managing secure, multi-tenant container and function-based services
  - QEMU microvm - A minimalist machine type without PCI nor ACPI support, designed for short-lived guests, and optimized for both boot time and footprint
  - Docker Sandboxes - The isolated, disposable environments designed to run AI coding agents in lightweight microVMs for enhanced security and system protection
  - Daytona - The secure infrastructure platform for running AI-generated code in isolated sandbox environments with sub-90ms creation times
  - Modal - An AI infrastructure platform that provides a serverless cloud for engineers to build and scale compute-intensive applications in thousands of isolated sandboxes
- Virtualization & Container Storage
  - virtiofs - A shared file system that lets virtual machines access a directory tree on the host
- Image Services & Distribution
  - Nydus - A powerful opensource filesystem solution to form a high-efficiency image distribution system for Cloud Native workloads, such as container images, software packages, etc

Cloud-Native Infrastructure

- App Runtimes & Scaling
  - KEDA (Kubernetes Event-driven Autoscaling) - A single-purpose and lightweight component that can be added into any cluster to provide event-driven scale for any container running in the environment
  - Dapr (Distributed Application Runtime) - A portable, event-driven runtime that makes it easy for any developer to build resilient, stateless, and stateful applications that run on the cloud and edge and embraces the diversity of languages and developer frameworks
  - V8 isolates - An independent instance of the engine with its own heap and its own garbage collector
- Serverless Computing
  - Knative - A Kubernetes-based platform to build, deploy, and manage modern serverless workloads
- Service Mesh & Discovery
  - Gateway API - The next generation of Kubernetes Ingress, Load Balancing, and Service Mesh APIs
  - Istio - An open source service mesh that layers transparently onto existing distributed applications
    - Kiali - The service mesh observability and configuration tool for Istio
  - Linkerd - An ultralight, security-first service mesh for Kubernetes
  - Hashicorp Consul - A service networking solution to connect and secure services across any runtime platform and public or private cloud
- Edge Proxies & Ingress
  - Envoy Proxy - An open source edge and service proxy
  - Traefik proxy - A leading modern open source reverse proxy and ingress controller
  - Contour - A high performance ingress controller for Kubernetes that provides the control plane for the Envoy edge and service proxy
  - Apache APISIX - An open source API Gateway to help you manage microservices, delivering the ultimate performance, security, and scalable platform for all your APIs and microservices
- Cloud-Native Networking
  - Project Calico - An open-source project that provides secure network connectivity, network security, and observability for containers, virtual machines, and native host-based workloads
  - Cilium - An open-source project that provides networking, security, and observability for cloud-native environments
  - Flannel - A simple and easy way to configure a layer 3 network fabric designed for Kubernetes

CI/CD & GitOps

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > SRE Process

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  ==== Delivery & Deployment

- Continuous Delivery Tools
  - Harness - A modern software delivery platform that uses AI and automation to streamline CI/CD, GitOps, and cloud cost management
  - Jenkins - An open source automation server which enables developers around the world to reliably build, test, and deploy their software
    - Blue Ocean for Jenkins Pipelines - A project that rethinks the user experience of Jenkins
    - Python Jenkins - A Python wrapper for the Jenkins REST API
    - JenkinsPipelineUnit - A testing framework to unit test Jenkins pipelines written in Groovy or Declarative
  - GitLab CI/CD - A part of GitLab that you can use to automate the builds, integration, and verification of your source code
  - GitHub Actions - A feature that makes it easy to automate all your software workflows
    - actionlint - A static checker for GitHub Actions workflow files
    - act - A tool to run your GitHub Actions locally
  - Azure Pipelines - A cloud service that you can use to automatically build and test your code project and make it available to other users
- Application Deployment
  - Kamal - A tool to deploy web apps anywhere

GitOps & Cloud-Native

- GitOps Style CD
  - ArgoCD - A declarative, GitOps continuous delivery tool for Kubernetes
  - FluxCD - A tool for keeping Kubernetes clusters in sync with sources of configuration (like Git repositories), and automating updates to configuration when there is new code to deploy
- Cloud-Native Application Delivery
  - Open Application Model - A specification for describing applications so that they can be deployed and managed across any platform
  - KubeVela - A modern software delivery platform that makes deploying and operating applications across today's hybrid, multi-cloud environments easier, faster and more

reliable

- Flagger - A progressive delivery tool that automates the release process for applications running on Kubernetes

Integrations & Registries

- Private Package Registries
  - JFrog Artifactory - A universal DevOps repository manager that allows you to store, manage, and distribute your software artifacts and their dependencies
  - GitLab Package Registry - A feature that allows you to publish and share packages for a variety of supported package managers
  - GitHub Packages - A software package hosting service that allows you to host your software packages privately or publicly
  - Nexus Repository Manager 3 - A sophisticated repository manager
  - Azure Artifacts - A service that enables you to create and share Maven, npm, NuGet, and Python package feeds from public and private sources

System Observability

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > SRE Process

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  ==== Instrumentation & Platforms

- Concepts
  - Observability - A measure of how well internal states of a system can be inferred from knowledge of its external outputs
- Instrumentation Libraries
  - OpenTelemetry - A vendor-neutral open source Observability framework for instrumenting, generating, collecting, and exporting telemetry data such as traces, metrics, and logs
  - Jaeger - An open source, distributed tracing platform used to monitor and troubleshoot workflows in complex distributed systems
  - Micrometer - A metrics instrumentation library for JVM-based applications
- Monitoring Tools
  - Uptime Kuma - An easy-to-use self-hosted monitoring tool
- Managed Platforms
  - Azure Monitor - A comprehensive solution for collecting, analyzing, and acting on telemetry from your cloud and on-premises environments

        - Kusto Query Language - A powerful tool to explore your data and discover patterns, identify anomalies and outliers, create statistical models, and more
        - App Insights - A feature of Azure Monitor, is an extensible Application Performance Management (APM) service for developers and DevOps professionals
    - AWS CloudWatch - A monitoring and observability service built for DevOps engineers, developers, site reliability engineers (SREs), and IT managers
    - Datadog - The integrated platform for monitoring & security
    - Sentry - An application monitoring platform that provides error tracking and performance monitoring to help developers see what matters and solve issues faster
- Self-hosted (advanced)
    - SigNoz - An open-source Datadog or New Relic alternative for logs, metrics, traces, dashboards, alerts, and more
- Visualization Tools
    - Grafana - The open source data visualization and monitoring solution
        - Grafonnet - A Jsonnet library for generating Grafana dashboards
    - Kibana - A free and open user interface that lets you visualize your Elasticsearch data and navigate the Elastic Stack

Telemetry Shipment

- Data Shippers
    - Prometheus exporters - The services that expose Prometheus metrics
        - node-exporter - An exporter for hardware and OS metrics exposed by *NIX kernels
        - blackbox-exporter - A tool that allows blackbox probing of endpoints over HTTP, HTTPS, DNS, TCP, ICMP and gRPC
    - Grafana Alloy - An open source OpenTelemetry collector with built-in Prometheus pipelines and support for metrics, logs, traces, and profiles
    - Fluent Bit - A super fast, lightweight, and highly scalable logging, metrics, and traces processor and forwarder
    - Fluentd - An open source data collector, which lets you unify the data collection and consumption for a better use and understanding of data
    - Filebeat - A lightweight shipper for forwarding and centralizing log data
    - Logstash - An open source server-side data processing pipeline that ingests data from a multitude of sources, transforms it, and then sends it to your favorite "stash"
    - Telegraf - An open source server agent that helps you collect metrics from your stacks, sensors, and systems
    - Metricbeat - A lightweight shipper that you can install on your servers to periodically collect metrics from the operating system and from services running on the server

    - rsyslog - The rocket-fast system for log processing
- Vendor-specific Tools
    - Azure Monitor Agent - The agent that collects monitoring data from the guest operating system of Azure and hybrid virtual machines
    - Cloudwatch Agent - The agent you can use to collect both system-level metrics and log files from Amazon EC2 instances and on-premises servers

Telemetry Collection & Storage

- Datastore and Alerting Tools
    - Prometheus - An open-source systems monitoring and alerting toolkit
        - PromQL - The Prometheus Query Language
        - promtool - The command line utility for the Prometheus server
        - Awesome Prometheus Alerts - A collection of copy-pasteable Prometheus alerting rules spanning over 90 services and exporters
    - Alertmanager - A tool that handles alerts sent by client applications such as the Prometheus server
        - amtool - A CLI tool for interacting with the Alertmanager API
    - InfluxDB - A time series database built from the ground up to handle high write and query loads
        - InfluxQL - An SQL-like query language for interacting with data in InfluxDB
        - influx cli - The command line interface for InfluxDB 2.0
    - Grafana Mimir - An open source, horizontally scalable, highly available, multi-tenant, long-term storage for Prometheus
    - Grafana Loki - A horizontally-scalable, highly-available, multi-tenant log aggregation system inspired by Prometheus
        - LogQL - The query language for Loki
            - LogCLI - The command line interface for Loki
    - Grafana Tempo - An open source, easy-to-use and high-scale distributed tracing backend
        - TraceQL - A query language designed for selecting traces
    - ElasticSearch - An open source distributed, RESTful search and analytics engine, scalable data store, and vector database
        - Elastic Common Schema - An open source specification, developed with support from the Elastic user community
        - Ingest pipelines - A feature that lets you perform common transformations on your data before indexing
        - Dissect and Grok - The processors that let you extract structured fields out of a single text field

  - Graphite - A highly scalable real-time graphing system
  - Grafana Alerting - A feature that allows you to create and manage alerts for your data
  - OpenObserve - An open-source observability platform designed for modern applications

SRE (Site Reliability Engineering)

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > SRE Process

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- Site Reliability Engineering - A discipline that incorporates aspects of software engineering and applies them to infrastructure and operations problems
  - Service Level Objectives (SLOs) - A target value or range of values for a service level that is measured by a service level indicator (SLI)
  - Dickerson's Hierarchy of Service Reliability - A model that illustrates the foundational elements required to build and maintain reliable services, often visualized as a pyramid
  - The Four Golden Signals - The four key metrics (Latency, Traffic, Errors, and Saturation) that Google SREs use for monitoring user-facing systems
- Ishikawa diagram - A causal diagram created by Kaoru Ishikawa that shows the potential causes of a specific event

Fleet Management & Operations

- Fleet Management
  - AWS Systems Manager - A secure end-to-end management solution for resources on AWS and in multicloud and hybrid environments
  - Azure Automation - A cloud-based automation and configuration service that supports consistent management across your Azure and non-Azure environments
    - Azure Update Manager - A unified service to help manage and govern updates for all your machines
- Backup
  - Vendor-specific Tools
    - AWS Backup - A fully managed service that centralizes and automates data protection across AWS services, in the cloud, and on premises
    - Azure Backup - A service that provides simple, secure, and cost-effective solutions to back up your data and recover it from the Microsoft Azure cloud
  - K8s-specific Tools
    - Velero - An open source tool to safely back up and restore, perform disaster recovery, and migrate Kubernetes cluster resources and persistent volumes

    - Generic
        - Barman - A disaster recovery solution for PostgreSQL databases, designed to ensure business continuity by simplifying online hot backups
        - Restic - A fast, secure, efficient backup program
- Runbook Automation
    - RunDeck - An open source automation platform that helps you automate routine operational procedures in data center or cloud environments
- AIOps & Autonomous Agents
    - Azure SRE Agent - An AI-powered service designed to automate Site Reliability Engineering practices by monitoring, diagnosing, and helping resolve incidents
    - Mezmo Aura - An open-source agentic harness designed specifically for Site Reliability Engineering (SRE) and production AI operations

Chaos Engineering

- Concepts
    - Chaos Engineering - The practice of experimenting on a system in order to build confidence in the system's capability to withstand turbulent conditions in production
    - Principles of chaos engineering - The principles that define the practice of chaos engineering
- Chaos Engineering Tools
    - Litmus - A cloud-native chaos engineering framework for Kubernetes
    - Chaos Mesh - A cloud-native Chaos Engineering platform that orchestrates chaos on Kubernetes environments
    - Toxiproxy - A TCP proxy to simulate network and system conditions for chaos and resiliency testing
    - kubeinvaders - A gamified chaos engineering tool for Kubernetes

FinOps

- Concepts
    - FinOps principles - The cultural practice of bringing financial accountability to the variable spend model of cloud
- FinOps Tools
    - FinOps toolkit - A collection of tools, resources, and best practices for implementing FinOps in your organization
    - AWS Cost Explorer - A tool that enables you to view and analyze your costs and usage
    - Infracost - A tool that shows cloud cost estimates for Terraform, CloudFormation, and other infrastructure-as-code projects

- OpenCost - The open source solution for monitoring Kubernetes spend
- Cloud Custodian - A rules engine for managing public cloud accounts and resources

Performance & Load Testing

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > SRE Process

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- Performance Testing - The practice of evaluating how a system performs in terms of responsiveness and stability under a particular workload

Performance Testing Tools

- Hyperfine - A command-line benchmarking tool
- Locust - An easy-to-use, distributed, user load testing tool
- Grafana k6 - The open-source load testing tool that makes performance testing easy and productive for engineering teams
- Gatling - The load testing tool for programmers that helps engineering teams shift performance concerns left
- Apache Jmeter - A pure Java application designed to load test functional behavior and measure performance
- ab - A tool for benchmarking your Apache Hypertext Transfer Protocol (HTTP) server
- stress-ng - A tool that imposes configurable amounts of CPU, memory, I/O, and disk stress on the system
- sysbench - A scriptable multi-threaded benchmark tool based on LuaJIT
- fio - A tool that will spawn a number of threads or processes doing a particular type of I/O action as specified by the user
- iPerf - The ultimate speed test tool for TCP, UDP and SCTP
- plow - An HTTP(S) benchmarking tool written in Golang that conducts load testing with concurrent connections while displaying real-time performance metrics through both a web UI and terminal interface
- loadgen-rs - A h2load-compatible HTTP benchmark client written in Rust, supporting HTTP/1.1, HTTP/2, and HTTP/3 (QUIC) with commandline mode and distributed mode

04 - Security & Privacy

Security Foundations

:::note[Relevant DSS-P Skills]

- 4. Security > 4.1 Security Management > Security System Construction and Operation

- 4. Security > 4.1 Security Management > Security Management

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- Information security - The practice of protecting information by mitigating information risks
- Vulnerability - A weakness which can be exploited by a threat actor
- Threat - A potential negative action or event facilitated by a vulnerability
- Shared Responsibility Model - A security and compliance framework that outlines the responsibilities of cloud service providers (CSPs) and customers for securing every aspect of the cloud environment

Common Threats & Attack Vectors

- Malware - Any software intentionally designed to cause disruption to a computer, server, client, or computer network
- Ransomware - A type of malware from cryptovirology that threatens to publish the victim’s personal data or perpetually block access to it unless a ransom is paid
- Social engineering - The psychological manipulation of people into performing actions or divulging confidential information
- Phishing - A type of social engineering where an attacker sends a fraudulent message designed to trick a person into revealing sensitive information
- Business Email Compromise (BEC) - A type of phishing attack in which an attacker impersonates a high-level executive and attempts to trick an employee or customer into transferring money or sensitive data
- Infostealer - A type of Trojan horse designed to gather information from a system
- Mirai (malware) - A malware that turns networked devices running Linux into remotely controlled bots that can be used as part of a botnet in large-scale network attacks
- Think before you Click(Fix) - A social engineering technique that tricks users into running malicious commands on their devices by taking advantage of their target’s tendency to solve minor technical issues

Modern Security Architectures

- Zero trust security model - An approach to the design and implementation of IT systems where trust is never granted implicitly and verification is required for everyone
- Mutual authentication - A process in which both parties in a communications link authenticate each other

Security Training & Competitions

- Capture the flag (cybersecurity) - A hacking contest where participants use specialized knowledge and techniques to find hidden "Flags" (answers) and compete for the highest total score

- Platforms
  - CTFd - The easiest Capture The Flag platform to host your own cyber security workshop, providing a rock solid base that is easily customizable with themes and plugins

Cryptography & Data Protection

:::note[Relevant DSS-P Skills]

- 4. Security > 4.2 Security Technology > Secure Design, Development, and Construction

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==== Core Cryptography

Hashing

- Hash Function
  - MD5 - A cryptographically broken but still widely used hash function producing a 128-bit hash value
  - SHA-2 (SHA-224, SHA-256, SHA-384, SHA-512) - A set of cryptographic hash functions designed by the United States National Security Agency (NSA)
  - Bcrypt - A password-hashing function based on the Blowfish cipher
  - Scrypt - A password-based key derivation function created by Colin Percival

Symmetric-key Cryptography

- Symmetric-key algorithm - Algorithms for cryptography that use the same cryptographic keys for both the encryption of plaintext and the decryption of ciphertext
- Block Cipher
  - AES - A specification for the encryption of electronic data established by the U.S. National Institute of Standards and Technology (NIST) in 2001
  - Salsa20 ChaCha - A variant of Salsa20 that increases the diffusion per round while achieving the same or slightly better performance
- MAC (Message Authentication Code)
  - HMAC - A specific type of message authentication code (MAC) involving a cryptographic hash function and a secret cryptographic key
- Modes of Operation
  - CBC (Cipher block chaining) - A mode of operation for a block cipher where a block of plaintext is XORed with the previous ciphertext block before being encrypted
  - GCM (Galois/Counter Mode) - A mode of operation for symmetric-key cryptographic block ciphers which is widely adopted for its performance
  - CCM - A mode of operation for cryptographic block ciphers designed to provide both

authentication and confidentiality

Public-key Cryptography

- Digital signature - A mathematical scheme for verifying the authenticity of digital messages or documents
- Public-key cryptography - A cryptographic system that uses pairs of keys
  - RSA - A public-key cryptosystem that is widely used for secure data transmission
  - EdDSA - A digital signature scheme using a variant of Schnorr signature based on twisted Edwards curves
- Key Agreement
  - Diffie-Hellman key exchange - A method of securely exchanging cryptographic keys over a public channel
  - Elliptic-curve Diffie-Hellman - A key agreement protocol that allows two parties to establish a shared secret over an insecure channel
- Encryption Schemes
  - RSAES-PKCS1-v1_5 - An older Encryption/decryption Scheme (ES) was first standardized in version 1.5 of PKCS #1 and is known to be vulnerable
  - RSAES-OAEP - A padding scheme that enhances RSA encryption by adding randomness and preventing partial decryption, it was standardized in PKCS#1 v2 and RFC 2437
- Signature Schemes
  - RSASSA-PKCS1-v1_5 - A Signature Scheme with Appendix (SSA) was first standardized in version 1.5 of PKCS #1 and is considered unforgeable according to Jager et al. (2018)
  - DSA - A public-key cryptosystem and Federal Information Processing Standard for digital signatures, it is based on the mathematical concept of modular exponentiation and the discrete logarithm problem
  - ECDSA - A variant of the Digital Signature Algorithm (DSA) that utilizes elliptic-curve cryptography
- Key formats
  - PKCS #1: RSA Cryptography Specifications - A standard that provides the basic definitions of and recommendations for implementing the RSA algorithm for public-key cryptography
  - PKCS #12: Personal Information Exchange Syntax - A file format for storing multiple cryptographic objects in a single file
- Cryptographic Standards & Formats
  - Cryptographic Message Syntax - The IETF's standard for cryptographically protected messages, used by cryptographic schemes and protocols to digitally sign, digest, authenticate, or encrypt any form of digital data

Public Key Infrastructure (PKI)

- Public Key Infrastructure (PKI) - A set of roles, policies, hardware, software and procedures needed to create, manage, distribute, use, store and revoke digital certificates
- Certificate authority (CA) - An entity that stores, signs, and issues digital certificates
- Registration authority (RA)
- Validation authority (VA)
- Protocols & Standards
  - Simple Certificate Enrollment Protocol - A protocol for enrolling X.509 certificates in a secure and automated manner
- Validation & Enrollment
  - Domain Control Validation - A process used by certificate authorities (CAs) to verify that the person or organization requesting a certificate has control over the domain(s) listed in the certificate
- Trust Stores
  - Certifi - A carefully curated collection of Root Certificates for validating the trustworthiness of SSL certificates while verifying the identity of TLS hosts
- Public key certificate - An electronic document used to prove the validity of a public key
  - Domain Validated (DV)
  - Organization Validated (OV)
  - Extended Validation (EV)
- Let’s Encrypt - A nonprofit Certificate Authority providing TLS certificates
  - certbot - A free, open source software tool for automatically using Let’s Encrypt certificates on manually-administrated websites to enable HTTPS
  - lego - A Let’s Encrypt client and ACME library written in Go
  - cfssl - Cloudflare’s PKI toolkit
- ACME (Automatic Certificate Management Environment) - A communications protocol for automating interactions between certificate authorities and their users' web servers
- mkcert.org - A simple tool for making locally-trusted development certificates
- cert-manager - A powerful and extensible X.509 certificate controller for Kubernetes and OpenShift

Secrets Management

- Vault - A tool for securely accessing secrets like API keys, passwords, or certificates
- OneCLI - An open-source credential vault and proxy gateway for AI agents that stores secrets in an encrypted vault and injects them into agent requests without exposing keys
- SOPS - An editor of encrypted files that supports YAML, JSON, ENV, INI and BINARY

formats

- git-secret - A bash tool to store your private data inside a git repo
- Kubernetes Ecosystem
  - Sealed Secrets - A Kubernetes controller and tool for one-way encrypted Secrets
  - Secrets Store CSI Driver - A driver that allows Kubernetes to mount multiple secrets, keys, and certs stored in enterprise-grade external secrets stores into pods as a volume
  - External Secrets Operator - A Kubernetes operator that integrates external secret management systems like AWS Secrets Manager, HashiCorp Vault, Google Secrets Manager, Azure Key Vault, and IBM Cloud Secrets Manager
- Vendor Services
  - Azure Key Vault - A cloud service to safeguard cryptographic keys and other secrets used by cloud apps and services
  - Google Cloud Secret Manager - A secure and convenient storage system for API keys, passwords, certificates, and other sensitive data
  - AWS Key Management Service - A service that makes it easy for you to create and manage cryptographic keys
  - AWS Secrets Manager - A secrets management service that helps you protect access to your applications, services, and IT resources

Applied Cryptography & Tools

- Advanced Cryptography Topics
  - Post-quantum cryptography - Cryptographic algorithms that are thought to be secure against a cryptanalytic attack by a quantum computer
  - Information Hiding
    - Steganography - The practice of concealing a file, message, image, or video within another file, message, image, or video
    - Digital watermarking - A kind of marker covertly embedded in a noise-tolerant signal such as an audio, video or image data
- End-to-end Encryption Tools
  - age - A simple, modern and secure file encryption tool, format, and Go library
  - Pretty Good Privacy (PGP) - A data encryption and decryption computer program that provides cryptographic privacy and authentication for data communication
  - OpenPGP - A non-proprietary protocol for exchanging public keys and encrypted messages
  - keys.openpgp.org - A public key server for OpenPGP
  - GnuPG - A free software replacement for the PGP cryptographic software suite
  - Gpg4win - A Windows software package that facilitates the secure transport of emails

and files with the help of OpenPGP

- Cryptographic Libraries
  - PyCryptodome - A self-contained Python package of cryptographic primitives
  - Python cryptography - A package designed to expose cryptographic primitives and recipes to Python developers
  - Go Cryptography - A collection of Go cryptography libraries
  - Botan - A cryptography library written in C++

Identity & Access Management (IAM)

:::note[Relevant DSS-P Skills]

- 4. Security > 4.2 Security Technology > Secure Design, Development, and Construction
- 2. Data Preparation & Utilization > 2.3 Data Management > Improvement of Data Quality and Safety

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==== Integrated IAM

- Identity management - A framework of policies and technologies for ensuring that the proper people in an enterprise have the appropriate access to technology resources
- Self-hosted IAM Platforms
  - FusionAuth CE - The self-hosted, community supported version of FusionAuth
  - KeyCloak - An open source identity and access management solution
  - FreeIPA - An integrated security information management solution combining Linux, 389 Directory Server, MIT Kerberos, NTP, DNS, and a certificate system
- Cloud IAM Services
  - Microsoft Entra ID - A cloud-based identity and access management service
  - AWS IAM - A service that helps you securely control access to AWS resources
  - Amazon Cognito - A service that lets you add user sign-up, sign-in, and access control to your web and mobile apps
  - Auth0 - A flexible, drop-in solution to add authentication and authorization services to your applications
- Directory service - A service that maps the names of network resources to their respective network addresses
  - LDAP - An open, vendor-neutral, industry standard application protocol for accessing and maintaining distributed directory information services
  - OpenLDAP - An open source implementation of the Lightweight Directory Access Protocol
  - 389 Directory Server - A free and open source software project developed by Red

Hat for Linux systems

- Specifications
  - Decentralized Identifiers (DIDs) - A new type of identifier that enables verifiable, decentralized digital identity
  - System for Cross-domain Identity Management (SCIM) - A specification designed to make managing user identities in cloud based applications and services easier

Authentication (AuthN)

- Authentication - The act of proving an assertion, such as the identity of a computer system user
- Multi-factor authentication (MFA) - A method that requires multiple verification methods for access
- Single sign-on (SSO) - A service that allows one login for multiple applications
- Protocols & Standards
  - OpenID Connect - A simple identity layer on top of the OAuth 2.0 protocol
  - SAML - A standard for logging users into applications
  - WS-Federation - A specification that defines mechanisms used to broker trust and manage identities, attributes and authentication between participating Web services
  - FIDO2 (WebAuthn, CTAP, Passkeys) - A set of specifications that enables users to leverage common devices to easily and securely authenticate to online services
    - Relying party - The website or online service that wants to verify a user's identity (e.g., your bank's website)
    - Authenticator - The device or software that securely stores cryptographic keys and performs authentication for the user.
    - Client - The software on the user's device, typically a web browser or operating system component, that communicates between the Relying Party and the Authenticator.
    - WebAuthn - An API for accessing Public Key Credentials
    - CTAP - A protocol that enables an external authenticator to communicate with a client platform
    - Passkeys - A phishing-resistant replacement for passwords
  - SPIFFE - The Secure Production Identity Framework for Everyone
  - Kerberos - A computer network authentication protocol that works on the basis of tickets
  - SSPI (Security Support Provider Interface) - A Win32 API that allows an application to use various security models available on a computer or network without changing the interface to the security system
- Credentials & Tokens

  - Basic authentication - A method for an HTTP user agent to provide a username and password when making a request
  - JSON Web Token (JWT) - An Internet standard for creating data with optional signature and/or optional encryption whose payload holds JSON that asserts some number of claims
    - nodejs jsonwebtoken - An implementation of JSON Web Tokens for Node.js
  - TOTP (Time-Based One-Time Password) - A temporary passcode, generated by an algorithm, for use in authenticating access to computer systems
- Platforms & Tools
  - Dex - A Federated OpenID Connect Provider
  - Firebase Authentication - A service that provides backend services, easy-to-use SDKs, and ready-made UI libraries to authenticate users to your app
  - Supabase Auth - A service that provides user management and access control for Supabase projects
  - ReCAPTCHA - A CAPTCHA system that enables web hosts to distinguish between human and automated access to websites
  - Microsoft Authentication Library (MSAL) - A library that helps developers integrate authentication and authorization into applications
  - Application Default Credentials (ADC) - A mechanism used by Google Cloud client libraries to automatically find credentials based on the application environment
  - Limen - A lightweight, composable authentication and authorization library for Go that provides sessions, password hashing, OAuth, and CSRF protection

Authorization (AuthZ)

- Authorization - The function of specifying access rights/privileges to resources
- Access Control Models
  - Access control list (ACL) - A list of permissions associated with a system resource
  - Attribute-based access control (ABAC) - A model grants access based on user attributes
  - Discretionary access control (DAC) - A model allows users to control access to their own resources
  - Mandatory access control (MAC) - A model enforces access policies based on security labels
  - Role-based access control (RBAC) - A policy-neutral access-control mechanism defined around roles and privileges
    - Azure RBAC - A system that enables fine-grained access management of Azure resources
      - Security principal kinds: User, Group, Service Principal, Managed Identity
    - Entra ID RBAC - A system that provides fine-grained access management of

Microsoft Entra resources

- Protocols & Standards
  - OAuth 2.0 Authorization Framework - An open standard for access delegation
    - Resource owner - the user who owns the data or resources that are being accessed
    - Resource server - the server that hosts the protected resources
    - Client - an application or service that wants to access the resources on behalf of the resource owner
    - Authorization server - the server that issues access tokens to the client
- Platforms & Tools
  - Permify - An open-source authorization service that helps you to create any kind of authorization system with its Golang API
  - Azure Shared Access Signature (SAS) - A signed URI that points to one or more storage resources and includes a token that specifies the permissions and interval of access

Secure Development Lifecycle (DevSecOps)

:::note[Relevant DSS-P Skills]

- 4. Security > 4.2 Security Technology > Secure Design, Development, and Construction

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  ==== Secure Design & Modeling

- Threat modeling - A process by which potential threats can be identified, enumerated, and prioritized from a hypothetical attacker’s point of view
- OWASP Threat Modeling - Guidance from the OWASP Security Culture project on integrating threat modeling into the development lifecycle
- STRIDE model - A mnemonic for categorizing computer security threats into six categories
- MITRE ATT&CK - A globally-accessible knowledge base of adversary tactics and techniques
  - Tactics: The high-level objectives or goals that an adversary aims to achieve during an attack.
  - Techniques: The specific methods or ways adversaries achieve their tactical objectives.
  - Procedures: The specific implementations or variations of techniques that adversaries utilize in their operations.
- Modeling Tools
  - OWASP Threat Dragon - A free, open-source, cross-platform threat modeling

application

  - threatspec - A tool that allows you to define threat models as code

Secure Development Practices

- Secure Software Development Framework (SSDF) - A set of fundamental, sound, and secure software development practices
- Microsoft Security Development Lifecycle (SDL) - A software development process that helps developers build more secure software and address security compliance requirements while reducing development cost
- OWASP Application Security Verification Standard (ASVS) - A standard for performing application-level security verifications
- OWASP Security Champions - A program to embed security expertise and culture within development teams
- OWASP Cheat Sheet Series - A collection of concise cheat sheets on various security topics
- OWASP LLM Top 10 - A guide to the top 10 risks, vulnerabilities, and mitigations for developing and securing generative AI and large language model applications across the development, deployment, and management lifecycle
- Coding Standards
  - MISRA C - A set of guidelines for the use of the C programming language in safety-critical embedded systems, originally developed for the automotive industry
  - CERT Secure Coding Standards - A collection of programming security guidelines for C, C++, Java, Perl, and other languages published by Carnegie Mellon's CERT

Application Security Testing (AST)

- Static Analysis (SAST)
  - SonarQube Server - A self-managed, automatic code review tool that systematically helps you deliver clean code
  - GitLab SAST - A tool that checks your source code for known vulnerabilities
  - Bandit (for Python) - A tool designed to find common security issues in Python code
  - Semgrep OSS - A fast, open-source, static analysis tool for finding bugs and enforcing code standards
  - Fluid attacks - A security tool that allows you to find vulnerabilities in your source code, containers and dependencies
- Dynamic Analysis (DAST)
  - ZAP - The world's most widely used web app scanner, free and open source, and a community based GitHub Top 1000 project that anyone can contribute to
  - Nuclei - A fast and customizable vulnerability scanner powered by the global security community and built on a simple YAML-based DSL

  - sqlmap - An open source penetration testing tool that automates the process of detecting and exploiting SQL injection flaws and taking over of database servers
  - Evilginx - A man-in-the-middle attack framework used for phishing login credentials along with session cookies
- Secret Detection
  - GitLab Secret Detection - A tool that scans your repository's history for secrets
  - Gitleaks - A SAST tool for detecting and preventing hardcoded secrets like passwords, api keys, and tokens in git repos
  - secretlint - A pluggable linting tool to prevent committing credentials
  - Talisman - A tool that installs a hook to your repository to ensure that potential secrets or sensitive information do not get committed
  - TruffleHog - A tool that scans your environment for secrets, digging deep into commit history and branches
  - Whispers - A static code analysis tool designed for parsing various common data formats in search of hardcoded credentials
- AI-orchestrated Penetration Testing
  - PentestGPT - An automated penetration testing framework powered by Large Language Models (LLMs)
  - PentAGI - An open-source, fully autonomous AI agent system designed for automated security testing
  - Strix - A set of autonomous AI agents that act like real hackers to run code dynamically, find vulnerabilities, and validate them through actual proof-of-concepts
  - CAI - A lightweight, open-source framework that empowers security professionals to build and deploy AI-powered offensive and defensive automation
  - HexStrike AI - An advanced MCP server that lets AI agents autonomously run 150+ cybersecurity tools for automated pentesting, vulnerability discovery, bug bounty automation, and security research
  - Zen AI Pentest - An autonomous, AI-powered penetration testing framework that combines cutting-edge language models with professional security tools

Infrastructure as Code (IaC) Security

- Trivy - A comprehensive and versatile security scanner
- checkov - A static code analysis tool for scanning infrastructure as code (IaC) files for misconfigurations
- Haskell Dockerfile Linter - A smarter Dockerfile linter that helps you build best practice Docker images
- kube-score - A tool that performs static code analysis of your Kubernetes object definitions
- kubesec - A security risk analysis for Kubernetes resources

- PSRule - A cross-platform PowerShell module with commands to test and verify infrastructure as code (IaC)
  - PSRule for Azure - A suite of rules to validate Azure resources and infrastructure as code (IaC) using PSRule
- ComplianceAsCode - A project that provides security automation content in various formats like SCAP, Bash, and Ansible
- complyctl - A command-line tool that uses OSCAL to streamline compliance assessment activities

Software Supply Chain Security (SSCS)

- Composition Analysis (SCA)
  - SBOM Generation
    - Syft - A CLI tool and Go library for generating a Software Bill of Materials (SBOM) from container images and filesystems
    - OWASP CycloneDX format - A lightweight Software Bill of Materials (SBOM) standard designed for use in application security contexts
    - SPDX format - An open standard for communicating Software Bill of Materials (SBOM) information
  - Vulnerability Scanning
    - Grype - A vulnerability scanner for container images and filesystems
    - OSV-scanner - The official vulnerability scanner for OSV
    - Safety - A tool that checks your installed dependencies for known security vulnerabilities
    - Clair - An open-source project for the static analysis of vulnerabilities in application containers
    - GitLab Container Scanning - A tool that checks your Docker images for known vulnerabilities
    - JFrog Xray - An application security tool that identifies vulnerabilities and license compliance issues across the software supply chain
  - License & Dependency Analysis
    - Feluda - A blazing fast dependency graph generator for Python projects
- Frameworks & Assessment
  - SLSA framework - A security framework of standards and controls to prevent tampering, improve integrity, and secure packages and infrastructure
  - in-toto - A framework to protect software supply chain integrity
  - OpenSSF Scorecard - An automated tool that assesses a number of important heuristics ("checks") associated with software security and assigns each check a score of 0-10

- Provenance & Artifact Metadata
  - GUAC - An open source tool that aggregates software security metadata into a high fidelity graph database
- Secure Distribution & Updates
  - The Update Framework (TUF) - A framework for securing software update systems, providing protection even against attackers that compromise the repository or signing keys
- Code Signing & Integrity
  - Sigstore (Fulcio, Rekor, Cosign) - A new standard for signing, verifying and protecting software
- Notable Attacks
  - Shai-Hulud npm Supply Chain Attack - A self-propagating worm that harvests sensitive data via post-install scripts and automatically publishes malicious versions of accessible packages to spread further

Runtime & Operational Security

:::note[Relevant DSS-P Skills]

- 4. Security > 4.1 Security Management > Incident Response and Business Continuity
- 4. Security > 4.2 Security Technology > Security Operation, Maintenance, and Monitoring

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==== Cloud-Native Application Protection (CNAPP)

- The 4 Cs of Cloud-Native Systems - A defense-in-depth approach that divides security strategies into four distinct layers to provide multilayered protection for cloud-native applications
- Microsoft Defender for Cloud - A cloud-native application protection platform (CNAPP) with a set of security measures and practices designed to protect cloud-based applications
- Cloud Security Posture Management (CSPM)
  - AWS Security Hub - A cloud security posture management (CSPM) service that performs security best practice checks, aggregates alerts, and enables automated remediation
  - cnquery - A cloud-native, graph-based security tool that allows you to query your entire infrastructure as data
- Cloud Workload Protection Platform (CWPP)
  - Amazon Inspector - An automated security assessment service that helps improve the security and compliance of applications deployed on AWS
  - Falco - The cloud-native runtime security project

  - Tracee - A powerful runtime security and forensics tool for Linux
  - ClamAV - An open source antivirus engine for detecting trojans, viruses, malware & other malicious threats
  - YARA - The pattern matching swiss knife for malware researchers

Security Operations & Monitoring (SecOps)

- Detection & Response
  - Endpoint detection and response (EDR) - A cybersecurity technology that addresses the need for continuous monitoring and response to advanced threats
  - Extended detection and response (XDR) - A SaaS-based, vendor-specific, security threat detection and incident response tool
  - Managed detection and response (MDR) - An outsourced service that provides organizations with threat hunting services and responds to threats once they are discovered
- SIEM & SOAR
  - Security orchestration, automation and response (SOAR) - A stack of compatible software programs that allow an organization to collect data about security threats
  - Microsoft Sentinel - A scalable, cloud-native, security information and event management (SIEM) and security orchestration, automation, and response (SOAR) solution
  - Amazon GuardDuty - A threat detection service that continuously monitors for malicious activity and unauthorized behavior
- Detections & Auditing
  - Sigma Detection Format - A generic and open signature format that allows you to describe relevant log events in a straightforward manner
  - AWS CloudTrail - An AWS service that helps you enable operational and risk auditing, governance, and compliance of your AWS account
  - AWS Config - A service that enables you to assess, audit, and evaluate the configurations of your AWS resources

Policy Enforcement

- Open Policy Agent (OPA) - An open source, general-purpose policy engine that unifies policy enforcement across the stack
  - Rego - A high-level declarative language used to write policies for OPA
  - Conftest - A utility to help you write tests against structured configuration data
- Cloud Policy Engines
  - Azure Policy - A service to achieve real-time cloud compliance at scale with consistent resource governance

- Kubernetes Policy Engines
  - Gatekeeper - A customizable validating webhook that enforces policies executed by the Open Policy Agent (OPA)
  - Kyverno - A policy engine designed for Kubernetes

Digital Forensics & Incident Response (DFIR)

- Concepts
  - Computer security incident management - The monitoring and detection of security events on a computer or computer network, and the execution of proper responses to those events
  - Digital forensics - A branch of forensic science that involves the recovery, investigation, examination, and analysis of material found in digital devices, often in relation to mobile devices and computer crime
  - Computer forensics - A branch of digital forensic science pertaining to evidence found in computers and digital storage media
- Tools & Platforms
  - Volatility - The world's most widely used framework for extracting digital artifacts from volatile memory (RAM) samples
  - Autopsy - A digital forensics platform and graphical interface to The Sleuth Kit and other digital forensics tools

Secure Communications & Networking

:::note[Relevant DSS-P Skills]

- 4. Security > 4.2 Security Technology > Secure Design, Development, and Construction

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  ==== Transport Layer Security (TLS)

- Transport Layer Security (TLS) - A cryptographic protocol designed to provide communications security over a computer network
- Server Name Indication (SNI) - An extension to the Transport Layer Security (TLS) computer networking protocol
- Tools & Libraries
  - testssl.sh - A free command line tool which checks a server's service on any port for the support of TLS/SSL ciphers and protocols
  - OpenSSL library - A software library for applications that secure communications over computer networks against eavesdropping
  - stunnel - A proxy designed to add TLS encryption functionality to existing clients and servers

    - Squid SSL Bump - A feature of Squid proxy that allows it to intercept, decrypt, and re-encrypt SSL/TLS traffic
- Vulnerabilities
    - Lucky Thirteen attack - A timing attack against the TLS protocol that allows an attacker to decrypt ciphertext

Secure Shell (SSH)

- Secure Shell (SSH) - A cryptographic network protocol for operating network services securely over an unsecured network
- Tools & Libraries
    - OpenSSH - The premier connectivity tool for remote login with the SSH protocol
    - PuTTY - A free implementation of SSH and Telnet for Windows and Unix platforms
    - ssh-audit - A tool for SSH server & client configuration auditing
    - keychain - A manager for ssh-agent, typically started from ~/.bash_profile

Web Application Security

- 3-D Secure - A security protocol designed to be an additional security layer for online credit and debit card transactions
- Security Mechanisms & Policies
    - SOP (Same-origin policy) - An important concept in the web application security model
    - CORS (Cross-Origin Resource Sharing) - A mechanism that allows restricted resources on a web page to be requested from another domain
    - CSP (Content Security Policy) - An added layer of security that helps to detect and mitigate certain types of attacks, including Cross-Site Scripting (XSS) and data injection attacks
    - HSTS (HTTP Strict Transport Security) - A web security policy mechanism that helps to protect websites against protocol downgrade attacks and cookie hijacking
    - Cross-origin isolation - A web security feature that allows a web page to use powerful features like SharedArrayBuffer and performance.measureUserAgentSpecificMemory()
- Common Vulnerabilities & Attacks
    - Cross-site request forgery (CSRF) - A type of malicious exploit of a website where unauthorized commands are submitted from a user that the web application trusts
    - Cross-site scripting (XSS) - A type of security vulnerability typically found in web applications
    - DNS rebinding - A type of attack that allows a malicious web page to bypass the same-origin policy by exploiting the Domain Name System

    - SSRF (Server-side request forgery) - A type of exploit where an attacker can abuse the functionality on the server to read or modify internal resources
- Privacy & Transparency
    - Privacy sandbox - Google's initiative to create web technologies that protect people's privacy online and give companies and developers the tools to build thriving digital businesses
    - security.txt - A proposed standard which allows websites to define security policies for researchers

Firewalls & Network Protection

- Web Application Firewall (WAF)
    - AWS WAF - A web application firewall that helps protect your web applications or APIs against common web exploits and bots
    - Azure Web Application Firewall - A cloud-native service that protects web apps from common web-hacking techniques and vulnerabilities
- Network-level Protection
    - AWS Shield - A managed Distributed Denial of Service (DDoS) protection service that safeguards applications running on AWS
    - Azure DDoS Protection - A service that provides countermeasures against the most sophisticated DDoS threats
    - Fail2ban - An intrusion prevention software framework that protects computer servers from brute-force attacks
    - Snort (IPS) - The foremost Open Source Intrusion Prevention System (IPS) in the world
- Host-based Firewalls
    - netfilter (iptables, nftables) - A framework inside the Linux kernel that enables packet filtering, network address translation, and other packet mangling
    - Uncomplicated Firewall (ufw) - A program for managing a netfilter firewall

Email & DNS Security

- Email Security
    - STARTTLS - A mechanism allows plain text communication protocols to upgrade to an encrypted connection
    - SASL (Simple Authentication and Security Layer) - A framework for authentication and data security in Internet protocols
    - SPF (Sender Policy Framework) - An email authentication method designed to detect forging sender addresses during the delivery of the email
    - DKIM (DomainKeys Identified Mail) - An email authentication method designed to detect forged sender addresses in email

  - DMARC (Domain-based Message Authentication, Reporting & Conformance) - An email authentication, policy, and reporting protocol
  - S/MIME - A standard provides cryptographic security services like authentication, message integrity, non-repudiation, privacy, and data security for electronic messaging applications
- DNS Security
  - DNSSEC - A feature of the Domain Name System (DNS) that authenticates responses to domain name lookups
  - DNS over TLS (DoT) - A security protocol for encrypting and wrapping Domain Name System (DNS) queries and answers via the Transport Layer Security (TLS) protocol
  - DNS over HTTPS (DoH) - A protocol for performing remote Domain Name System (DNS) resolution via the HTTPS protocol
- Tools & Libraries
  - OpenDKIM - A community effort develops and maintains a C library for producing DomainKeys Identified Mail-aware applications and an open-source milter for providing the service

Governance, Risk, and Compliance (GRC)

:::note[Relevant DSS-P Skills]

- 1. Business Transformation > 1.3 Management of Transformation Activities > Risk & Compliance
- 4. Security > 4.1 Security Management > Security Management
- 4. Security > 4.1 Security Management > Privacy Protection

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==== Data Governance

- Unity Catalog - A universal catalog for data and AI that provides interoperability, openness, and unified governance across various formats and platforms
- Microsoft Purview - A unified approach to help organizations secure and govern data across their heterogeneous data estate
- Amazon DataZone - A data management service that makes it faster and easier for customers to catalog, discover, share, and govern data stored across AWS, on premises, and third-party sources

AI Governance & Security

- METR - A research nonprofit that scientifically measures whether and when AI systems might threaten catastrophic harm to society
- Microsoft Agent 365 - A centralized governance and management platform designed to oversee autonomous AI agents within an enterprise environment

Regulations & Standards

- Laws & Regulations
  - General Data Protection Regulation (GDPR) - The toughest privacy and security law in the world
    - Data subject requests (DSR)
    - Breach notification
    - Data protection impact assessment (DPIA)
  - California Consumer Privacy Act (CCPA) - A state statute intended to enhance privacy rights and consumer protection for residents of California
  - Cyber Resilience Act - A regulation that aims to safeguard consumers and businesses buying or using products or software with a digital component by introducing mandatory cybersecurity requirements
- Security & Privacy Frameworks
  - NIST SP 800-53 - A catalog of security and privacy controls for all U.S. federal information systems except those related to national security
  - OSCAL - The Open Security Controls Assessment Language, a NIST-led initiative that provides open, machine-readable formats (XML, JSON, YAML) to automate security and compliance processes
  - ISO/IEC 27001 / 27002 - The international standard for information security management systems
- Industry & Audit Standards
  - PCI-DSS - The global standard for payment card data security
  - SOC 2 - A voluntary compliance standard for service organizations which specifies how organizations should manage customer data
  - FIPS 140-2 - A U.S. government computer security standard used to approve cryptographic modules
- Hardening & Implementation Guides
  - Security Technical Implementation Guides (STIGs) - The configuration standards for DOD IA and IA-enabled devices/systems
  - CIS Controls and Benchmarks - A publication of best practice guidelines for computer security

Vulnerability Management & Reporting

- Bug bounty program - A monetary reward given to ethical hackers for successfully discovering and reporting a vulnerability or bug to the application's developer
- Identifiers & Enumerations
  - CVE (Common Vulnerabilities and Exposures) - A system that provides a reference-method for publicly known information-security vulnerabilities and exposures

  - CWE (Common Weakness Enumeration) - A category system for software weaknesses and vulnerabilities
  - OSV (Open Source Vulnerability) - A vulnerability database and triage infrastructure for open source projects
- Scoring & Prioritization
  - CVSS (Common Vulnerability Scoring System) - A free and open industry standard for assessing the severity of computer system security vulnerabilities
  - EPSS (Exploit Prediction Scoring System) - A data-driven framework for estimating the probability that a software vulnerability will be exploited in the wild
  - KEV (Known Exploited Vulnerabilities) - A catalog that contains vulnerabilities that have been exploited in the wild
  - SSVC (Stakeholder-Specific Vulnerability Categorization) - A vulnerability management methodology that assesses the risk a vulnerability poses to an organization and provides a corresponding decision-making process
- Protocols & Databases
  - Security Content Automation Protocol (SCAP) - A multi-purpose framework of specifications that supports automated configuration, vulnerability and patch checking
  - NVD (U.S. National Vulnerability Database) - The U.S. government repository of standards based vulnerability management data
  - SARIF - A standard format for the output of static analysis tools

System & Personal Security

:::note[Relevant DSS-P Skills]

- 4. Security > 4.1 Security Management > Security System Construction and Operation
- 4. Security > 4.2 Security Technology > Secure Design, Development, and Construction

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==== OS & Endpoint Security

- Address space layout randomization (ASLR) - A computer security technique involved in memory protection that prevents exploitation of memory vulnerabilities by randomly arranging the address space positions of key data areas of a process
- W^X - A security feature that ensures that every page in a process's address space is either writable or executable, but not both
- Control-flow integrity - A general term for computer security techniques that prevent a wide variety of malware attacks from redirecting the flow of execution of a program
- TPM (Trusted Platform Module) - A specification for a secure cryptoprocessor, a dedicated microcontroller designed to secure hardware through integrated cryptographic keys

- Linux Mandatory Access Control
  - SELinux - A set of kernel modifications and user-space tools that have been added to various Linux distributions
  - AppArmor - A Linux kernel security module that allows the system administrator to restrict programs' capabilities with per-program profiles
  - bubblewrap - A low-level unprivileged sandboxing tool used by Flatpak and similar projects
- Linux Fine-grained Access Control
  - Linux capabilities - A feature that grants some of the power of the superuser to a process, while not granting all of them
- General Scanning
  - OpenSCAP - An open source implementation of the Security Content Automation Protocol (SCAP)
  - Lynis - A security auditing tool for systems running Linux, macOS, or Unix-based operating system

Personal Security Tools

- Password Managers
  - 1Password - A password manager and secure vault platform for identities, credentials, and secrets across humans and AI agents
  - pass - The standard unix password manager
  - gokey - A simple vaultless password manager in Go
  - Buttercup - A free, open-source and cross-platform password manager

05 - Data Science & Engineering

Foundational Concepts

:::note[Relevant DSS-P Skills]

- 2. Data Preparation & Utilization > 2.1 Strategic Utilization of Data and AI > Understanding and Utilization of Data and AI

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  ==== General Data Concepts & Principles

- Data - Any sequence of one or more symbols; datum is a single symbol of data
- Metadata - The data that provides information about other data, but not the content of the data
- Big data - The data sets that are too large or complex to be dealt with by traditional data-processing application software

- Data model - An abstract model that organizes elements of data and standardizes how they relate to one another and to the properties of real-world entities
- Data orientation - A perspective of data that emphasizes the data itself, rather than the applications that use the data
- DIKW pyramid - A class of models representing purported structural and/or functional relationships between data, information, knowledge, and wisdom
- Garbage in, garbage out - A concept in computer science and information and communications technology that the quality of the output is determined by the quality of the input
- Data cleansing - The process of detecting and correcting (or removing) corrupt or inaccurate records from a record set, table, or database
- Data lifecycle management - A policy-based approach to managing the flow of an information system's data throughout its life cycle
- Master data management - A technology-enabled discipline in which business and IT work together to ensure the uniformity, accuracy, stewardship, semantic consistency and accountability of the enterprise's official shared master data assets
- Data quality - A measure of the condition of data based on factors such as accuracy, completeness, consistency, reliability and whether it's up to date
- Single source of truth - The practice of structuring information models and associated data schema such that every data element is mastered (or edited) in only one place

Core Data Engineering & Database Concepts

- Concurrency control - The mechanism ensuring that correct results for concurrent operations are generated efficiently
- CRUD operations - The four basic operations of persistent storage: create, read, update, and delete
- Shard - A horizontal partition of data in a database or search engine
- ETL - A three-phase process where data is extracted from an input source, transformed, and loaded into an output data container
- ELT - A data integration process where raw data is moved from a source system to a destination resource, such as a data warehouse, and then transformed for use
- Data pipeline - A set of data processing elements connected in series, where the output of one element is the input of the next one
- Data governance - A data management concept concerning the capability that enables an organization to ensure that high data quality exists throughout the complete lifecycle of the data
- Data lineage - The process of understanding, recording, and visualizing data as it flows from data sources to consumption
- Online transaction processing (OLTP) - A type of data processing that consists of executing a number of transactions occurring concurrently

- Online analytical processing (OLAP) - An approach to answering multi-dimensional analytical queries swiftly in computing
- Search engine indexing - The collecting, parsing, and storing of data to facilitate fast and accurate information retrieval

Data Governance, Quality & Architecture

- Data Catalog - A centralized metadata repository that helps organizations manage and discover data assets
- Data Stewardship - A set of practices and processes for managing an organization's data assets to ensure quality, security, and compliance
- Data Privacy - The right and ability of an individual to determine what happens to information about themselves
- Data Contract - An explicit agreement on data structure, quality, and semantics between data producers and consumers
- Schema Evolution - The process of modifying a database schema while maintaining compatibility with existing data and applications
- Dimensional Modeling - A database design technique used to optimize data warehouses for analytical queries using facts and dimensions

Data Science Toolkit

:::note[Relevant DSS-P Skills]

- 2. Data Preparation & Utilization > 2.2 AI and Data Science > Mathematical Statistics, Multivariate Analysis, and Data Visualization

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  ==== Programming Languages & Libraries

- Python - A programming language that lets you work quickly and integrate systems more effectively
  - Awesome Python - A curated list of awesome Python frameworks, libraries, tools, and resources
  - Pandas - A fast, powerful, flexible and easy to use open source data analysis and manipulation tool
  - Polars - A blazingly fast DataFrame library for manipulating structured data
  - Narwhals - A lazy-first, type-agnostic, and framework-agnostic dataframe library in Python
  - NumPy - The fundamental package for scientific computing with Python
  - SciPy - Fundamental algorithms for scientific computing in Python
  - SymPy - A Python library for symbolic mathematics

    - SageMath - A free open-source mathematics software system licensed under the GPL
    - statsmodels - A Python module that provides classes and functions for the estimation of many different statistical models, as well as for conducting statistical tests, and statistical data exploration
- R - A free software environment for statistical computing and graphics
    - Tidyverse - An opinionated collection of R packages designed for data science
- GNU Octave - A high-level language, primarily intended for numerical computations
- Wolfram Language - A symbolic language, deliberately designed with the breadth and unity needed to develop powerful programs quickly

Specialized & Scientific Tools

- latexify - A Python package to compile a fragment of Python source code to a corresponding LaTeX expression
- handcalcs - A Python library to render Python calculation code automatically in Latex, but in a manner that mimics how one might format their calculation if it were written with a pencil
- NetworkX - A Python package for the creation, manipulation, and study of the structure, dynamics, and functions of complex networks
- JAX - A Python library for accelerator-oriented array computation and program transformation

Data Sources & Geospatial

- GeoLite2 - A set of free geolocation and ASN data in downloadable database and web service formats

Spreadsheet & Collaborative Data Platforms

- Microsoft Excel - The industry-leading spreadsheet software program and a powerful data visualization and analysis tool
- Grist - A relational spreadsheet that combines the familiar interface of a spreadsheet with the power and structure of a relational database
- NocoBase - A scalability-first, open-source no-code platform designed for building complex business applications and internal tools
- NocoDB - An open-source, no-code platform that turns any database into a smart spreadsheet, providing a collaborative interface for relational databases
- Airtable - A platform that combines the flexibility of a spreadsheet with the power of a database to help teams manage their work

Interactive Computing Environments

- JupyterLab - A web-based interactive development environment for notebooks, code, and data
- Jupyter Notebook - The original web application for creating and sharing computational documents
  - VSCode Jupyter Extension - A VS Code extension that provides basic notebook support for language kernels supported in the environment
- nbviewer - A simple way to share Jupyter Notebooks
- R Markdown - An authoring framework that helps you create dynamic analysis documents combining code, rendered output, and prose
- Wolfram Notebooks - A powerful environment for exploration and communication, combining text, literate programming, graphics and custom interactive elements
- Voila - A tool that turns Jupyter notebooks into standalone web applications

Data Visualization

:::note[Relevant DSS-P Skills]

- 2. Data Preparation & Utilization > 2.2 AI and Data Science > Mathematical Statistics, Multivariate Analysis, and Data Visualization

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  ==== Common Chart Types

- Histogram - A representation of the distribution of numerical data
- Scatter plot - A type of plot or mathematical diagram using Cartesian coordinates to display values for typically two variables for a set of data
- Box plot - A method for graphically demonstrating the locality, spread and skewness groups of numerical data through their quartiles
- Error bar - A graphical representation of the variability of data used on graphs to indicate the uncertainty in a reported measurement
- Heat map - A technique that shows magnitude of a phenomenon as color in two dimensions
- Choropleth map - A type of thematic map in which a set of pre-defined areas is colored or patterned in proportion to a statistical variable
- Proportional symbol map - A type of thematic map that uses symbols that vary in size to represent a quantitative variable
- Tag cloud - A novelty visual representation of text data

Visualization Tools & Libraries

- Python Libraries

    - matplotlib - A comprehensive library for creating static, animated, and interactive visualizations in Python
    - seaborn - A Python data visualization library based on matplotlib
    - Plotly - The interactive, open-source, and browser-based graphing library for Python (includes Plotly Express)
    - WordCloud for Python - A little word cloud generator in Python
- JavaScript Libraries
    - D3 - The JavaScript library for bespoke data visualization
    - GoJS - A JavaScript library that lets you easily create interactive diagrams in web browsers
    - Chart.js - A simple yet flexible JavaScript charting library for the modern web
    - Recharts - A composable charting library built on React components
    - Tabulator - An easy to use, simple to code, fully featured, interactive JavaScript library for creating tables and data grids
- Grammars & Other
    - gnuplot - A portable command-line driven graphing utility
    - ggplot2 - A system for declaratively creating graphics, based on The Grammar of Graphics
    - Vega - A visualization grammar, a declarative language for creating, saving, and sharing interactive visualization designs
    - Vega-Lite - A high-level grammar of interactive graphics

Dashboarding & Web Apps

- Dash - The original low-code framework for rapidly building data apps in Python, R, Julia, and F#
- Panel - A powerful Python library that lets you create interactive web apps and dashboards
- Streamlit - A faster way to build and share data apps

Distributed Systems

:::note[Relevant DSS-P Skills]

- 2. Data Preparation & Utilization > 2.3 Data Management > Data Engineering (Design, Collection, Integration, Provision)

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  ==== Distributed Computing Principles

- Distributed computing - A field of computer science that studies such systems

- Single point of failure - A part of a system that, if it fails, will stop the entire system from working
- Fault tolerance - The property that enables a system to continue operating properly in the event of the failure of some of its components
- Load balancing - The process of distributing a set of tasks over a set of resources, with the aim of making their overall processing more efficient
- Fallacies of distributed computing - A set of assertions describing false assumptions that programmers new to distributed applications invariably make
- Byzantine fault - A condition of a distributed system, where components may fail and there is imperfect information about whether a component has failed
  - Consensus - A fault-tolerant mechanism that is used in distributed systems to achieve the necessary agreement on a single data value among distributed processes or systems
- CAP theorem - A theorem stating that any distributed data store can provide only two of the following three guarantees: Consistency, Availability, and Partition tolerance
- BASE properties - A database model that prioritizes availability over consistency

Consensus & Replication Strategies

- Raft Consensus Algorithm - A consensus algorithm designed to be more understandable than Paxos, enabling safe state machine replication across clusters
- Paxos Algorithm - A family of protocols for solving consensus in a network of unreliable or asynchronous processors
- Data Replication - The frequent electronic copying of data from a computer or server to another location, computer, or server
  - Master-Slave Replication - A pattern where one primary node accepts writes and slaves replicate data
  - Consensus - A fault-tolerant mechanism that is used in distributed systems to achieve the necessary agreement on a single data value among distributed processes or systems

Distributed Patterns & Observability

- Circuit Breaker Pattern - A design pattern to prevent cascading failures in distributed systems
- Distributed Tracing - A method for profiling and monitoring applications, especially those built using microservices architecture
- Event Sourcing - A pattern where all changes to application state are stored as a sequence of immutable events

Distributed Storage Systems

- Distributed File Systems
  - HDFS - A distributed file system designed to run on commodity hardware
  - IPFS - A peer-to-peer hypermedia protocol designed to make the web faster, safer, and more open
    - Kubo - A Go implementation of IPFS
- Object storage - A computer data storage architecture that manages data as objects
  - Amazon S3 - An object storage service offering industry-leading scalability, data availability, security, and performance
  - Azure Blob Storage - The Microsoft's object storage solution for the cloud, optimized for storing massive amounts of unstructured data
  - Azure Data Lake Storage (ADLS) - A scalable and secure data lake for high-performance analytics workloads
  - Google Cloud Storage - A RESTful online file storage web service for storing and accessing data on Google Cloud Platform infrastructure
  - Cloud Storage for Firebase - The service letting you upload and share user generated content, such as images and video
  - Supabase Storage - The service making it simple to store and serve large files like photos and videos
  - Self-hosted (advanced)
    - Ceph - An open-source, distributed storage system
    - MinIO - A high-performance, S3 compatible object store
  - Tooling
    - s5cmd - A very fast S3 and local filesystem execution tool
    - Rclone - A command-line program to manage files on cloud storage
    - Azure Storage Explorer - A standalone app making it easy to work with Azure Storage data on Windows, macOS, and Linux
    - Azurite - An open-source Azure Storage emulator

Mathematics & Statistics

:::note[Relevant DSS-P Skills]

- 2. Data Preparation & Utilization > 2.2 AI and Data Science > Mathematical Statistics, Multivariate Analysis, and Data Visualization

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  ==== Base Mathematics

- Algebra - A branch of mathematics that deals with abstract systems, known as algebraic

structures, and the manipulation of expressions within those systems

  - Boolean algebra - A branch of algebra that differs from elementary algebra in that the values of the variables are the truth values true and false, usually denoted by 1 and 0, and it uses logical operators such as conjunction (and), disjunction (or), and negation (not)
  - Elementary algebra - A branch of mathematics that encompasses the basic concepts of algebra
    - Equation - A mathematical formula that expresses the equality of two expressions, by connecting them with the equals sign =
    - Logarithm - The exponent by which another fixed value, the base, must be raised to produce that number
  - Abstract algebra - The study of algebraic structures, which are sets with specific operations acting on their elements
  - Linear algebra - The branch of mathematics concerning linear equations, linear maps, and their representations in vector spaces and through matrices
    - Vector space - A set whose elements, often called vectors, can be added together and multiplied ("scaled") by numbers called scalars
    - Matrix - A rectangular array of numbers or other mathematical objects with elements or entries arranged in rows and columns, usually satisfying certain properties of addition and multiplication
    - Sparse matrix - A matrix in which most of the elements are zero
    - Rank - The dimension of the vector space generated (or spanned) by its columns
    - Determinant - A scalar-valued function of the entries of a square matrix
- Calculus - The mathematical study of continuous change, in the same way that geometry is the study of shape and algebra is the study of generalizations of arithmetic operations
  - Differential calculus - A subfield of calculus that studies the rates at which quantities change
  - Integral calculus - The continuous analog of a sum, and is used to calculate areas, volumes, and their generalizations
  - Differential equation - An equation that relates one or more unknown functions and their derivatives
- Geometry - A branch of mathematics concerned with properties of space such as the distance, shape, size, and relative position of figures
  - Trigonometry - A branch of mathematics concerned with relationships between angles and side lengths of triangles
  - Coordinate system - A system that uses one or more numbers, or coordinates, to uniquely determine and standardize the position of the points or other geometric elements on a manifold such as Euclidean space
  - Euclidean distance - The length of the line segment between two points in a Euclidean space

- Category theory - A general theory of mathematical structures and their relations
  - Functor - A mapping between categories
- Root mean square - The square root of the mean of the squares of a set of numbers
- Transforms
  - Discrete cosine transform - A transform that expresses a finite sequence of data points in terms of a sum of cosine functions oscillating at different frequencies
  - Discrete Fourier transform - A discrete version of the Fourier transform that converts a finite sequence of equally-spaced samples of a function into a same-length sequence of equally-spaced samples of the discrete-time Fourier transform (DTFT)
- Related Resources
  - NIST Digital Library of Mathematical Functions - The definitive reference for the special functions of applied mathematics
    - Notations - A list of notations used in the library

Probability & Information Theory

- Probability theory - The branch of mathematics concerned with probability
  - Bayes' theorem - A mathematical rule for inverting conditional probabilities, allowing the probability of a cause to be found given its effect
  - Central limit theorem (CLT) - A theorem that states that, under appropriate conditions, the distribution of a normalized version of the sample mean converges to a standard normal distribution
- Information theory - A scientific study of the quantification, storage, and communication of digital information
  - Entropy - The average level of 'information', 'surprise', or 'uncertainty' inherent in a random variable’s possible outcomes

Statistics & Numerical Methods

- Statistics - A discipline that concerns the collection, organization, analysis, interpretation, and presentation of data
  - Sampling - The selection of a subset of individuals from within a statistical population to estimate characteristics of the whole population
  - Errors and residuals - The measures of the deviation of an observed value of an element of a statistical sample from its "true value"
  - Standard deviation - A measure of the amount of variation of the values of a variable about its average
  - Root mean square deviation - The square root of the average of the squared differences between the predicted values and the actual values
  - F-score - A measure of predictive performance in statistical analysis of binary classification and information retrieval systems

    - Correlation - A kind of statistical relationship between two random variables or bivariate data
        · Pearson correlation coefficient - A correlation coefficient that measures linear correlation between two sets of data
    - Hypothesis testing - A method of statistical inference used to decide whether the data provide sufficient evidence to reject a particular hypothesis
        · Null hypothesis - A typical statistical theory which suggests that no statistical relationship and significance exists in a set of given single observed variable, between two sets of observed data and measured phenomena
        · Confidence interval (CI) - A range of values which is likely to contain (in repeated sampling) the true value of an unknown statistical parameter, such as a population mean
        · P-value - The probability of obtaining test results at least as extreme as the result actually observed, under the assumption that the null hypothesis is correct
- Numerical methods
    - Significant figures - The specific digits within a number that is written in positional notation that carry both reliability and necessity in conveying a particular quantity
- Resources
    - Openstax Introductory Statistics - An open-source textbook for introductory statistics courses
    - OpenIntro Statistics - A dynamic take on the traditional curriculum, being successfully used at Community Colleges to the Ivy League

Data Formats & Architecture

:::note[Relevant DSS-P Skills]

- 2. Data Preparation & Utilization > 2.3 Data Management > Data Engineering (Design, Collection, Integration, Provision)
- 2. Data Preparation & Utilization > 2.3 Data Management > Improvement of Data Quality and Safety

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==== Data Formats & Table Formats

- Apache Parquet - An open source, column-oriented data file format designed for efficient data storage and retrieval
- Apache ORC - The smallest, fastest columnar storage for Hadoop workloads
- Apache Arrow - A universal columnar format and multi-language toolbox for fast data interchange and in-memory analytics
- BSON - A binary-encoded serialization of JSON-like documents
- Apache Avro - The leading serialization format for record data, and first choice for

streaming data pipelines

- Delta Lake - An open-source storage framework that enables building a format agnostic Lakehouse architecture with compute engines
- Apache Iceberg - The open table format for huge analytic datasets
- Apache Hudi - The Streaming Data Lake Platform

Data Architectures & Methodologies

- Data warehouse - A system used for reporting and data analysis and is a core component of business intelligence
- Data lake - A system or repository of data stored in its natural/raw format, usually object blobs or files
- Data lakehouse - A new, open architecture that combines the best elements of data lakes and data warehouses
- Medallion Architecture - A data design pattern used to logically organize data in a lakehouse
- CRISP-DM - An open standard process model that describes common approaches used by data mining experts

Data Governance & Metadata Management

- Apache Atlas - A scalable and extensible set of core foundational governance services that enable enterprises to meet compliance requirements
- Collibra - An enterprise data governance platform providing a common language for data management
- Informatica Metadata Manager - A comprehensive metadata management solution for enterprise data governance
- OpenMetadata - An open-source metadata management platform for data discovery, governance, and collaboration

Data Quality & Validation

- Great Expectations - A Python library for defining, documenting, and testing data quality
- Apache Griffin - A data quality solution built on Apache Spark and Apache Hadoop for distributed data quality measurement
- Soda - A data quality monitoring solution that integrates with modern data stacks

Data Versioning & Schema Management

- Schema Registry - A hosted schema management service that centralizes schemas for Kafka topics
- Git-based Schema Management - Using Git repositories to version control database schemas

- DBT Contracts - Explicit data contracts defining input and output data requirements

Relational Databases (SQL)

:::note[Relevant DSS-P Skills]

- 2. Data Preparation & Utilization > 2.3 Data Management > Data Engineering (Design, Collection, Integration, Provision)

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  ==== SQL Fundamentals

- Foundational Concepts
  - Relational model - An approach to managing data using a structure and language consistent with first-order predicate logic
  - ACID properties - A set of properties of database transactions intended to guarantee data validity despite errors, power failures, and other mishaps
    - Atomicity, Consistency, Isolation, and Durability
  - Codd's Twelve Rules - A set of thirteen rules proposed by Edgar F. Codd to define what is required from a database management system in order for it to be considered relational
  - Database normalization - The process of organizing columns (attributes) and tables (relations) of a relational database to minimize data redundancy
- Languages & Dialects
  - Structured Query Language (SQL) - A domain-specific language used for managing data held in a relational database management system
    - Command Categories
      - DDL - Data Definition Language
      - DQL - Data Query Language
      - DML - Data Manipulation Language
      - DCL - Data Control Language
      - TCL - Transaction Control Language
    - SQL Join - A clause that combines columns from one or more tables in a relational database
    - Aggregate function - A function where the values of multiple rows are grouped together to form a single summary value
  - Transact-SQL - The proprietary extension to SQL used to program and manage SQL Server

Database Management Systems (DBMS)

- Client-Server RDBMS
  - PostgreSQL - An object-relational database management system (ORDBMS) based on POSTGRES, Version 4.2, developed at the University of California at Berkeley Computer Science Department
  - MySQL - The most popular Open Source SQL database management system, is developed, distributed, and supported by Oracle Corporation
  - MariaDB community Server - The open source relational database that is a community-developed fork of MySQL
- Distributed SQL
  - TiDB - An open-source distributed SQL database that supports Hybrid Transactional and Analytical Processing (HTAP) workloads
- Embedded / In-Process
  - SQLite - A C-language library that implements a small, fast, self-contained, high-reliability, and full-featured database engine
  - PGlite - A WASM build packaged into a TypeScript/JavaScript client library, that enables you to run the database in the browser, Node.js and Bun
  - DuckDB - An in-process SQL OLAP database management system
- Storage Engines
  - Storage Engine - A software component that a database management system uses to create, read, update and delete (CRUD) data from a database
  - InnoDB - A transactional storage engine for MySQL and MariaDB

Cloud & Managed Services

- Managed Database Services
  - Amazon RDS - A collection of managed services that makes it simple to set up, operate, and scale databases in the cloud
  - Amazon Aurora - A fully managed relational database engine offering high performance and availability at global scale for PostgreSQL, MySQL, and DSQL
  - Azure SQL Database - An intelligent, scalable, relational database service built for the cloud
  - Google Cloud SQL - A fully-managed database service that helps you set up, maintain, manage, and administer your relational databases on Google Cloud
  - Neon - A serverless, fault-tolerant, and scalable Postgres with a generous free tier

Connectivity & Tooling

- Connectivity APIs & ORMs

  - Connection pool - A cache of database connections maintained so that the connections can be reused when future requests to the database are required
  - ODBC - A standard application programming interface for accessing database management systems
  - JDBC - An API that allows access to virtually any tabular data source from the Java programming language
    - Jdbi - A library that provides a more idiomatic way to use the Java Database Connectivity API
  - Object-Relational Mapping (ORM) - A programming technique for converting data between incompatible type systems using object-oriented programming languages
    - Prisma - A next-generation ORM that makes it easy to build reliable and scalable applications with databases
    - Hibernate - An object-relational mapping tool for the Java programming language
    - SQLAlchemy - The Python SQL toolkit and Object Relational Mapper that gives application developers the full power and flexibility of SQL
    - GORM - The fantastic ORM library for Golang aims to be developer friendly
    - XORM - A Simple and Powerful ORM for Go
    - Diesel - A Safe, Extensible ORM and Query Builder for Rust
- Developer Libraries & Drivers
  - Vanna.AI - A Python package that uses retrieval augmentation to help generate accurate SQL queries using LLMs
  - Psycopg - The most popular PostgreSQL adapter for the Python programming language
- Database Clients & IDEs
  - pgAdmin - The most popular and feature rich Open Source administration and development platform for PostgreSQL
  - SSMS (SQL Server Management Studio) - An integrated environment for managing any SQL infrastructure, from SQL Server to Azure SQL Database
  - DB Browser for SQLite - A high quality, visual, open source tool to create, design, and edit database files compatible with SQLite
  - Azure Data Studio - A modern open-source, cross-platform hybrid data analytics tool designed to simplify the data landscape
  - Beekeeper Studio - A modern, easy to use, and good looking SQL editor and database manager
- Command-Line & Deployment Utilities
  - sqlcmd utility - A command-line utility for ad hoc, interactive execution of Transact-SQL statements and scripts and for automating T-SQL scripting tasks
  - sqlpackage - A command-line utility that automates several database development tasks

  - DAC (Data-tier Applications) - A logical database management concept that defines all of the SQL Server objects associated with a user's database
  - pgroll - A zero-downtime, reversible, schema migration tool for PostgreSQL
- Monitoring & Analysis
  - pgBadger - A PostgreSQL log analyzer built for speed with fully detailed reports and professional rendering

NoSQL & Specialized Databases

:::note[Relevant DSS-P Skills]

- 2. Data Preparation & Utilization > 2.3 Data Management > Data Engineering (Design, Collection, Integration, Provision)

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  ==== NoSQL Data Models

- Object-relational impedance mismatch - A set of conceptual and technical difficulties that are often encountered when a relational database management system (RDBMS) is being used by a program written in an object-oriented programming language or style
- Document Databases
  - MongoDB - A document database designed for ease of application development and scaling
  - DocumentDB - A powerful, scalable open-source document database built for modern applications
- Key-value Stores
  - etcd - A distributed, reliable key-value store for the most critical data of a distributed system
  - Redis - An in-memory data store used by millions of developers as a cache, vector database, document database, streaming engine
  - Dragonfly - A drop-in Redis replacement
- Graph Databases
  - Neo4j - A high-speed graph database with unbounded scale, security, and data integrity
    - Cypher - A declarative query language for property graph databases
  - LadybugDB - An embedded columnar graph database built for highly regulated industries
- Wide-columns Databases
  - Apache Cassandra - An open source NoSQL distributed database
  - Apache HBase - The Hadoop database, a distributed, scalable, big data store
  - ClickHouse - A fast, open-source OLAP (Online Analytical Processing) database

management system designed for real-time analytics

Vector & AI Databases

- Concepts
  - HNSW (Hierarchical Navigable Small Worlds) - A top-performing index for vector similarity search
- Vector Databases
  - Pinecone - A purpose-built vector database delivering relevant results at any scale
  - pgvector - An open-source vector similarity search for Postgres
  - ElasticSearch vector database - The world's most widely deployed, open source vector database
  - Weaviate - An open-source vector database that simplifies the development of AI applications
  - Milvus - A high-performance open-source vector database built to handle billions of vectors
  - Chroma - The AI-native open-source embedding database
  - Qdrant - A high-performance vector search engine built entirely in Rust that helps developers build AI retrieval at any scale

Cloud NoSQL Services

- Multi-model Databases
  - Azure Cosmos DB - A fully managed, serverless distributed database for modern app development
  - Amazon DynamoDB - A fully managed, serverless, key-value NoSQL database designed to run high-performance applications at any scale
- Document Databases
  - Cloud Firestore - A cloud-hosted, NoSQL database that your Apple, Android, and web apps can access directly via native SDKs
- Graph Databases
  - Amazon Neptune - A fast, reliable, and fully managed graph database service that makes it easy to build and run applications that work with highly connected datasets
- Wide-columns Databases
  - Google Cloud Bigtable - A NoSQL wide-column database service for large analytical and operational workloads

Data Processing & Messaging

:::note[Relevant DSS-P Skills]

- 2. Data Preparation & Utilization > 2.3 Data Management > Data Engineering (Design, Collection, Integration, Provision)

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  ==== Enterprise Integration

- Enterprise Integration Patterns - A pattern language of 65 integration patterns that helps developers design and build distributed applications or integrate existing ones
- Apache Camel - An open-source integration framework that empowers you to quickly and easily integrate various systems consuming or producing data

Message Queuing & Event Streaming

- Concepts
  - Message Brokers - An intermediary computer program module that translates a message from the formal messaging protocol of the sender to the formal messaging protocol of the receiver
  - Dead-letter queue - A specialized queue used in message queuing systems to store messages that could not be delivered or processed successfully
- Messaging & Streaming Platforms (Software)
  - Apache Kafka - An open-source distributed event streaming platform
    - Apache Kafka Ecosystem
      - Kafbat UI - A versatile, fast, lightweight, and flexible web interface designed to monitor and manage Apache Kafka clusters
  - RabbitMQ - A reliable and mature messaging and streaming broker
- Cloud Services
  - Amazon Kinesis - A service making it easy to collect, process, and analyze real-time, streaming data
  - Azure Event Hubs - A highly scalable and reliable event streaming platform capable of ingesting millions of events per second
  - Azure Service Bus - A fully managed enterprise message broker with message queues and publish-subscribe topics

Batch Processing (ETL/ELT)

- Base Frameworks
  - Apache Hadoop - A framework that allows for the distributed processing of large data sets
    - mrjob - The easiest route to writing Python programs that run on the framework
  - Apache Spark - The unified engine for large-scale data analytics
    - PySpark - The Python API for the engine, allowing big data processing with the language

  - RAY - An open-source unified compute framework that makes it easy to scale AI and Python workloads
  - Joblib - A set of tools to provide lightweight pipelining in Python
- Workflow Orchestration & ETL Tools (Software)
  - Apache NiFi - An easy to use, powerful, and reliable system to process and distribute data
  - Apache Airflow - A platform to programmatically author, schedule, and monitor workflows
  - dbt - A unified platform for delivering trusted data that empowers teams to deliver reliable, governed data at scale
  - Dagu - A local-first workflow engine that provides a declarative, file-based, and self-contained platform to orchestrate tasks from a single binary that scales from a laptop to a distributed cluster
- Managed ETL & Data Integration Services
  - Azure Data Factory - The cloud ETL service for scale-out serverless data integration and data transformation
  - AWS Glue - A serverless data integration service that makes it easy to discover, prepare, move, and integrate data from multiple sources
  - Google Cloud Data Fusion - A fully managed, cloud-native data integration service that helps users efficiently build and manage ETL/ELT data pipelines

Stream Processing

- Stream Processing Engines (Software)
  - Spark Structured Streaming - A scalable and fault-tolerant stream processing engine built on the Spark SQL engine
  - Apache Storm - A free and open source distributed realtime computation system
  - Apache Flink - A framework and distributed processing engine for stateful computations over unbounded and bounded data streams
- Cloud Services
  - Google Cloud Dataflow - A fully managed streaming analytics service that minimizes latency, processing time, and cost through autoscaling and batch processing

Data Analytics & Search

:::note[Relevant DSS-P Skills]

- 2. Data Preparation & Utilization > 2.1 Strategic Utilization of Data and AI > Understanding and Utilization of Data and AI

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  ==== Search Engines & Platforms

- Web Search Engines
  - Google Search - The search engine that allows you to search the world's information, including webpages, images, videos and more
  - DuckDuckGo - The search engine that doesn't track you
- Answer Engines
  - Wolfram|Alpha - A computational knowledge engine that computes expert-level answers using breakthrough algorithms, knowledgebase and AI technology
  - Perplexity AI - An AI-powered answer engine that provides accurate, trusted, and real-time answers to any question
- Search Platforms and Tools
  - Azure AI Search - A fully managed, cloud-hosted service that unifies access to enterprise and web content for AI-powered search and retrieval-augmented generation
    - Reciprocal Rank Fusion (RRF) - An algorithm that evaluates the search scores from multiple, previously executed queries to produce a unified result set
  - ElasticSearch - An open source distributed, RESTful search and analytics engine, scalable data store, and vector database
    - Painless - A simple, secure scripting language designed specifically for use with the engine
    - ES|QL - A piped language that allows you to filter, transform, and analyze data stored in the engine
    - Kibana - The open source interface to query, analyze, visualize, and manage your data stored in the engine
    - Kibana Query Language - A simple text-based query language for filtering data
  - Apache Solr - The popular, blazing-fast, open source enterprise search platform built on Apache Lucene
    - Apache Lucene - A Java library providing powerful indexing and search features
  - Faiss - A library for efficient similarity search and clustering of dense vectors
  - Meilisearch - A lightning-fast search engine that fits effortlessly into your apps, websites, and workflow
  - TypeSense - A lightning-fast, open source, search-as-you-type engine for building delightful search experiences

Analytics Engines & Platforms

- Software & Managed Services
  - Apache Hive - A distributed, fault-tolerant data warehouse system that enables analytics at a massive scale
  - Presto - A distributed SQL query engine designed for fast, reliable, and efficient analytics at any scale

- Trino - A distributed SQL query engine designed to query large data sets distributed over one or more heterogeneous data sources
- Amazon EMR - A cloud big data platform for running large-scale distributed data processing jobs, interactive SQL queries, and machine learning applications
- Amazon Redshift - A fully managed, petabyte-scale data warehouse service in the cloud
- Amazon Athena - An interactive query service that makes it easy to analyze data directly in Amazon S3 and other data stores using standard SQL
- Databricks - The platform that allows your entire organization to use data and AI
- Microsoft Fabric - An end-to-end analytics solution with full-service capabilities including data movement, data lakes, data engineering, data integration, data science, real-time analytics, and business intelligence
  - Microsoft OneLake - A single, unified, logical data lake for your whole organization
  - Lakehouse vs Data Warehouse - A guide for choosing between a lakehouse and a data warehouse based on data volume, structure, and processing requirements
- Azure Synapse Analytics - An enterprise analytics service that accelerates time to insight across data warehouses and big data systems
- Google Cloud BigQuery - A fully managed, AI-ready data analytics platform that helps you maximize value from your data and is designed to be multi-engine, multi-format, and multi-cloud
- Amazon QuickSight - An AI-powered business intelligence service that enables users to analyze data, create visualizations, and gain insights from various enterprise data sources

Semantic Layer

- Cube - The agentic analytics platform to deploy AI agents to model, analyze, and report on your data
- Open Semantic Interchange (OSI) - The universal standard for semantic model exchange enabling semantic metadata interchange across analytics, AI, and BI platforms

06 - AI, Machine Learning & LLM

Foundations of AI & Machine Learning

:::note[Relevant DSS-P Skills]

- 2. Data Preparation & Utilization > 2.1 Strategic Utilization of Data and AI > Understanding and Utilization of Data and AI

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- AI Paradigms

  - Symbolic AI - The collection of all methods in artificial intelligence research that are based on high-level symbolic (human-readable) representations of problems, logic and search
  - Neuro-symbolic AI - A subfield of artificial intelligence that integrates neural methods with symbolic methods to combine the strengths of both approaches, resulting in AI systems that can be trained from raw data while preserving explainability and explicit reasoning
    - AlphaGeometry - A neuro-symbolic system made up of a neural language model and a symbolic deduction engine, which work together to find proofs for complex geometry theorems
  - Generative AI - A subset of artificial intelligence that uses generative models to produce text, images, videos, or other forms of data
  - Causal AI - A technique in artificial intelligence that builds a causal model and can thereby make inferences using causality rather than just correlation
  - Connectionism - An approach to the study of human mental processes and cognition that utilizes mathematical models known as connectionist networks or artificial neural networks
  - Expert system - A computer system emulating the decision-making ability of a human expert
  - Artificial general intelligence - A hypothetical type of artificial intelligence that matches or surpasses human capabilities across virtually all cognitive tasks
- Core Concepts
  - Embedding - A representation learning technique that maps complex, high-dimensional data into a lower-dimensional vector space of numerical vectors
  - Transfer learning - A machine learning technique where knowledge gained from one task is reapplied to improve performance on a different but related task
  - Mathematical model - An abstract description of a concrete system using mathematical concepts and language
  - Mathematical optimization - The selection of a best element, with regard to some criteria, from some set of available alternatives
  - Gradient descent - A first-order iterative algorithm for minimizing a differentiable multivariate function
  - Loss function - A function that maps an event or values of one or more variables onto a real number intuitively representing some cost associated with the event
  - Feature engineering - A preprocessing step in supervised machine learning and statistical modeling which transforms raw data into a more effective set of inputs
  - Overfitting - The production of an analysis that corresponds too closely to a particular set of data, and may therefore fail to fit additional data or predict future observations reliably
  - Bias–variance tradeoff - The relationship between a model's complexity, the accuracy of its predictions, and how well it can make predictions on previously unseen data

- Inductive bias - The set of assumptions that the learner uses to predict outputs of given inputs that it has not encountered
- Curse of dimensionality - The phenomena that arise when analyzing and organizing data in high-dimensional spaces that do not occur in low-dimensional settings

Machine Learning

:::note[Relevant DSS-P Skills]

- 2. Data Preparation & Utilization > 2.2 AI and Data Science > Machine Learning and Deep Learning

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==== Learning Paradigms

- Supervised learning - A paradigm in machine learning where algorithms learn from labeled data
  - Classification - The problem of identifying which of a set of categories (sub-populations) a new observation belongs to, on the basis of a training set of data containing observations
    - Logistic regression - A statistical model that models the probability of an event taking place by having the log-odds for the event be a linear combination of one or more independent variables
    - Support vector machine - A set of supervised learning models with associated learning algorithms that analyze data for classification and regression analysis
    - Naive Bayes classifier - A family of simple probabilistic classifiers based on applying Bayes' theorem with strong (naive) independence assumptions between the features
    - Decision tree learning - A method using a decision tree as a predictive model to go from observations about an item to conclusions about its target value
    - Ensemble learning - A method using multiple learning algorithms to obtain better predictive performance than could be obtained from any of the constituent learning algorithms alone
      - Random forest - An ensemble learning method for classification, regression and other tasks that operates by constructing a multitude of decision trees at training time
    - ROC curve - A graphical plot that illustrates the diagnostic ability of a binary classifier system as its discrimination threshold is varied
  - Regression - A set of statistical processes for estimating the relationships between a dependent variable and one or more independent variables
    - Ordinary least squares - A type of linear least squares method for choosing the unknown parameters in a linear regression model
    - Generalized linear model - A flexible generalization of ordinary least squares

regression

- ARIMA model - A generalization of an autoregressive moving average (ARMA) model, fitted to time series data either to better understand the data or to predict future points in the series

- Unsupervised learning - A type of machine learning in which models are trained using unlabeled dataset and are allowed to act on that data without previous training
  - Principal component analysis - A linear dimensionality reduction technique with applications in exploratory data analysis, visualization and data preprocessing
  - K-means clustering - A method of vector quantization that aims to partition n observations into k clusters in which each observation belongs to the cluster with the nearest mean
- Reinforcement learning - An area of machine learning concerned with how intelligent agents ought to take actions in an environment in order to maximize the notion of cumulative reward
  - Markov chain - A stochastic process that describes a sequence of events where the probability of each event depends only on the state attained in the previous event
  - Markov decision process - A mathematical framework for modeling decision making in situations where outcomes are partly random and partly under the control of a decision maker
  - Hidden Markov model - A statistical Markov model where the system being modeled is assumed to be a Markov process with unobserved (hidden) states
  - Multi-armed bandit - A problem in which a fixed limited set of resources must be allocated between competing (alternative) choices in a way that maximizes their expected gain
  - Value function - A function used in mathematical optimization and reinforcement learning that assigns a measure of desirability to states or actions
- ML Concepts & Techniques
  - Hyperparameter - A parameter whose value is used to control the learning process
  - Hyperparameter optimization - The problem of choosing a set of optimal hyperparameters for a learning algorithm
  - Early stopping - A form of regularization used to avoid overfitting when training a learner with an iterative method, such as gradient descent
  - Cross-validation - Any of various similar model validation techniques for assessing how the results of a statistical analysis will generalize to an independent data set
  - Anomaly detection - The identification of rare items, events or observations which raise suspicions by differing significantly from the majority of the data
    - One-class classification - The technique trying to identify objects of a specific class amongst all objects, by primarily learning from a training set containing only the objects of that class
  - Recommender system - An information filtering system that seeks to predict the 'rating' or 'preference' a user would give to an item

- ML Frameworks & Platforms
  - scikit-learn - A free software machine learning library for the Python programming language
    - libsvm - A Library for Support Vector Machines
  - ML.NET - An open-source, cross-platform machine learning framework for .NET developers
  - Crab - A Python library for building recommender systems
  - mlxtend - A Python library of useful tools for the day-to-day data science tasks
  - Prophet - A forecasting procedure for time series data that is fast and provides completely automated forecasts
  - Azure Machine Learning - An enterprise-grade machine learning service to build and deploy models faster
  - Amazon SageMaker - The service to build, train, and deploy machine learning (ML) models for any use case with fully managed infrastructure, tools, and workflows
  - Gradio - The fastest way to demo your machine learning model with a friendly web interface so that anyone can use it, anywhere

Neural Networks and Deep Learning

:::note[Relevant DSS-P Skills]

- 2. Data Preparation & Utilization > 2.2 AI and Data Science > Machine Learning and Deep Learning

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- Neural Network Fundamentals
  - Neural network - The computational models used in machine learning for finding patterns in data
  - Tensor - The mathematical objects represented as multidimensional arrays used in machine learning
  - Activation Functions
    - Sigmoid function - A mathematical function having a characteristic 'S'-shaped curve or sigmoid curve
    - Softmax function - A function that converts a vector of K real numbers into a probability distribution of K possible outcomes
  - Backpropagation - A widely used algorithm for training feedforward neural networks
  - Autoencoder - A type of artificial neural network used to learn efficient codings of unlabeled data (unsupervised learning)
  - Vanishing gradient problem - The difficulty encountered when training artificial neural networks with gradient-based learning methods and backpropagation, where gradients shrink as they back-propagate

- Deep Learning Concepts & Training
  - Deep Learning - A part of a broader family of machine learning methods based on artificial neural networks with representation learning
  - Stochastic gradient descent - An iterative method for optimizing an objective function with suitable smoothness properties
  - Fine tuning - An approach to transfer learning in which the weights of a pre-trained model are trained on new data
  - LoRA (machine learning) - A parameter-efficient fine-tuning technique for adapting pre-trained models to specific tasks with significantly fewer computational resources

Architectures

- Recurrent neural network - A class of artificial neural networks where connections between nodes can create cycles, allowing output from some nodes to affect subsequent input to the same nodes
  - LSTM - An artificial neural network used in the fields of artificial intelligence and deep learning, distinguished by feedback connections
- Convolutional neural network (CNN) - A class of artificial neural network, most commonly applied to analyze visual imagery
- Attention - A technique in the context of neural networks that mimics cognitive attention, enhancing the important parts of the input data and fading out the rest
  - FlashAttention - A fast and memory-efficient exact attention mechanism
  - Transformer - A deep learning architecture based on the multi-head attention mechanism
- DL Frameworks & Visualization
  - TensorFlow - An end-to-end open source platform for machine learning
    - TFDS - The collection of datasets ready to use with TensorFlow or other Python ML frameworks like Jax
    - Keras - The Python Deep Learning API designed for human beings, not machines
  - PyTorch - An open source machine learning framework that accelerates the path from research prototyping to production deployment
  - AttentionViz - A Global View of Transformer Attention
  - BertViz - A tool for visualizing Attention in NLP Models
- Reference Books
  - Neural Networks and Deep Learning - A free online book explaining the core ideas behind neural networks and deep learning
  - Deep Learning, MIT Press - The textbook intended to help students and practitioners enter the field of machine learning in general and deep learning in particular

Natural Language Processing (NLP)

:::note[Relevant DSS-P Skills]

- 2. Data Preparation & Utilization > 2.2 AI and Data Science > Machine Learning and Deep Learning

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- Linguistics Foundations
  - Morphology - The study of words, how they are formed, and their relationship to other words in the same language
  - Syntax - A linguistic field that is the study of how words and morphemes combine to form larger units like phrases and sentences
  - Semantics - The study of linguistic meaning, examining how words acquire meaning and how complex expressions derive meaning from their constituent parts
  - Symbol grounding problem - The challenge of connecting abstract symbols to the real-world objects or concepts they represent

Concepts & Vector Representations

- Okapi BM25 - A ranking function used by search engines to estimate the relevance of documents to a given search query based on a probabilistic retrieval framework
- Levenshtein distance - A string metric for measuring the difference between two sequences by counting the minimum number of single-character edits required to change one into the other
- n-gram - A sequence of n adjacent symbols in a particular order, used in fields like natural language processing and computational biology
- tf-idf (term frequency-inverse document frequency) - A statistical measure used in information retrieval to evaluate the importance of a word in a document relative to a collection or corpus, accounting for its general frequency
- Word embedding - A representation of a word in natural language processing, typically a real-valued vector that encodes its meaning such that words closer in vector space are expected to be similar in meaning
  - Word2vec - A technique in natural language processing for obtaining vector representations of words that capture information about their meaning based on surrounding words
  - fastText - Library for efficient text classification and representation learning
  - GloVe - Global Vectors for Word Representation
- Sentence embedding - A numerical vector representation of a sentence that encodes its meaningful semantic information
- NLP Libraries
  - Natural Language Toolkit - A leading platform for building Python programs to work with human language data

  - Gensim - A free open-source Python library for representing documents as semantic vectors
  - Kuromoji - An open source Japanese morphological analyzer written in Java
  - Kagome - An open source Japanese morphological analyzer written in pure golang
  - mecab-python3 - A Python wrapper for the MeCab morphological analyzer for Japanese text
  - jieba - A Python module for Chinese text segmentation

Computer Vision

:::note[Relevant DSS-P Skills]

- 2. Data Preparation & Utilization > 2.2 AI and Data Science > Machine Learning and Deep Learning

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  ==== Image Processing & Fundamentals

- OpenCV - An open source computer vision and machine learning software library
  - GoCV - A package for the Go programming language with bindings for OpenCV 4
- Pillow - A Python Imaging Library adding image processing capabilities
- scikit-image - A collection of algorithms for image processing in Python
- ImageMagick - A tool to create, edit, compose, or convert digital images

3D Vision & Geometry

- Open3D - An open-source library that supports rapid development of software that deals with 3D data
- Point Cloud Library (PCL) - A standalone, large scale, open source project for 2D/3D image and point cloud processing

Object Detection & Recognition

- YOLO (You Only Look Once) - An end-to-end object detection model designed for real-time detection
- Detectron2 - Facebook's next generation library that provides state-of-the-art detection and segmentation algorithms
- Mask R-CNN - An extension of Faster R-CNN that adds a branch for predicting object masks in parallel with bounding boxes

Pose & Body Estimation

- MediaPipe - A framework for building multimodal ML pipelines for perception tasks like pose estimation, hand tracking, and face detection

- OpenPose - A library capable of real-time multi-person key point detection

Face & Biometric Recognition

- face_recognition - A Python library that recognizes and manipulates faces from Python or from the command line

OCR & Text Recognition

- Tesseract OCR - An open source text recognition (OCR) Engine
  - gosseract OCR - A Go package for OCR (Optical Character Recognition), by using Tesseract C++ library
- EasyOCR - A ready-to-use OCR with 80+ supported languages and all popular writing scripts
- OCRmyPDF - A tool to add a searchable OCR text layer to PDF files
- Open Models
  - LLaVA - A novel end-to-end trained large multimodal model that combines a vision encoder and Vicuna for general-purpose visual and language understanding, achieving impressive chat capabilities mimicking spirits of the multimodal GPT-4 and setting a new state-of-the-art accuracy on Science QA

Speech & Audio Processing

:::note[Relevant DSS-P Skills]

- 2. Data Preparation & Utilization > 2.2 AI and Data Science > Machine Learning and Deep Learning

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  ==== Automatic Speech Recognition (ASR)

- Kaldi - A speech recognition toolkit written in C++ for acoustic modeling and language modeling
- DeepSpeech - An open source engine for speech-to-text powered by deep learning
- wav2vec 2.0 - A self-supervised learning approach for speech recognition pre-training
- Open Models
  - Whisper - A robust speech recognition model trained via large-scale weak supervision

Text-to-Speech (TTS) & Voice Synthesis

- gTTS (Google Text-to-Speech) - A Python library and CLI tool to interface with Google's Text-to-Speech API
- Tacotron 2 - A neural network architecture for speech synthesis based on sequence-to-

sequence models with attention

Audio Processing & Tools

- librosa - A Python library for audio and music analysis
- PyAudio - Python bindings for PortAudio, the cross-platform audio I/O library
- SoX (Sound eXchange) - The Swiss Army knife of sound processing programs
- Praat - A software program for the analysis of speech in phonetics

Voice Activity Detection & Audio Enhancement

- webrtcvad - A Python wrapper for the WebRTC voice activity detector
- SileroVAD - An open-source voice activity detector trained on large datasets

Speaker Identification & Voice Biometrics

- Resemblyzer - A Python package for speaker embedding-based speaker recognition
- PyannoteAudio - A Python toolkit for speaker diarization and speaker change detection

Generative AI & Large Language Models (LLMs)

:::note[Relevant DSS-P Skills]

- 2. Data Preparation & Utilization > 2.1 Strategic Utilization of Data and AI > AI Implementation and Operation

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- Core Concepts
  - Vision Language Models (VLM) - An exciting class of models that can understand images and text
  - Diffusion model - A class of latent variable generative models in machine learning that learn to generate new data by reversing a gradual noising process
  - Multimodal learning - A deep learning approach that combines and processes diverse data types such as text, audio, images, or video for a more holistic understanding of complex information

Model Providers & Aggregators

- Anthropic - The API providing access to Anthropic's Claude models
- OpenAI - The platform for building applications with OpenAI's models
- DeepSeek - An AI model research and development company that focuses on building advanced large language models and artificial intelligence infrastructure
- Kimi - An AI assistant platform by Moonshot AI featuring the K2 model with long-context

capabilities, designed for coding assistance, deep research, and multi-agent workflows

- Gemini Developer APIs - The API that gives you access to the latest Gemini models from Google
- Hugging Face Serverless Inference API - The API allowing inference on models hosted on the Hugging Face Hub
- OpenRouter - A unified interface for LLMs
- Open Models
  - Llama - The open-source AI models you can fine-tune, distill and deploy anywhere
  - Gemma - A family of lightweight, state-of-the-art open models built from the same research and technology used to create the Gemini models
  - Mistral - A family of open-source and commercial generative AI models
  - OLMo - A state-of-the-art, truly open language model and framework to build and study the science of language models

Standards & Model Formats

- GGUF - A file format for storing models for inference with GGML and executors based on GGML
- ONNX - An open format built to represent machine learning models
- Safetensors - A simple format for storing tensors safely

Model Interface SDKs & Clients

- Libraries & SDKs
  - Go OpenAI - The Go client libraries for OpenAI API
  - Google Gen AI SDK - The Python SDK for Google's generative AI models
  - Instructor - A Python library designed to extract structured, validated data from Large Language Models (LLMs)
  - OmniAI - A minimalist library for interfacing with LLMs
  - Outlines - A library that guarantees structured outputs during generation directly from any large language model by enforcing compliance with JSON Schema, regular expressions, or context-free grammars
  - Ruby OpenAI - A Ruby wrapper for the OpenAI API
  - RubyLLM - The one beautiful Ruby API for GPT, Claude, Gemini, and more

Techniques & Methods

- Retrieval-augmented generation (RAG) - A technique that enables large language models to retrieve and incorporate new information from external data sources
  - dsRAG - A high-performance retrieval engine for unstructured data

- AWQ (Activation-aware Weight Quantization) - An efficient and accurate low-bit weight quantization (INT3/4) for LLM compression and acceleration
- GraphRAG - A data pipeline and transformation suite that is designed to extract meaningful, structured data from unstructured text using the power of LLMs
- Prompt Engineering Guide - A comprehensive resource for learning and applying prompt engineering techniques to effectively utilize large language models and build AI agents
- CRAFT framework - A structured method for crafting clear and precise AI prompts by defining context, role, action, format, and tone

Development Tools & Utilities

- LiteLLM - A Python SDK and AI Gateway (Proxy) that allows users to call over 100 Large Language Models (LLMs) using a unified OpenAI input/output format
- RedCandle - A Ruby gem for running state-of-the-art language models locally (via Rust's Candle)
- Unsloth AI - A platform providing tools and services for easily fine-tuning and training Large Language Models (LLMs) to achieve faster and more efficient AI training
- LLM - A CLI utility and Python library for interacting with Large Language Models

Benchmarking & Analysis

- ARC-AGI - The benchmark measuring progress toward artificial general intelligence by testing skill-acquisition efficiency on novel tasks that are intuitive for humans but challenging for AI systems
- OSWorld - A scalable, real computer environment for evaluating multimodal agents on 369 open-ended tasks spanning web applications, desktop software, and cross-application workflows across Ubuntu, Windows, and macOS
- FrontierMath - An AI benchmark consisting of extremely challenging mathematical problems, including open research problems authored by expert mathematicians, ranging from undergraduate to research-level difficulty
- MRCR v2 - A multi-round context recall benchmark that evaluates LLMs on their ability to retrieve and use information from extended multi-turn conversation histories
- Artificial Analysis - An independent analysis of AI models and API providers, helping users understand the AI landscape
- Arena - A platform designed for benchmarking and comparing various AI models, including both large language models (LLMs) and vision-language models (VLMs)

Agentic AI

:::note[Relevant DSS-P Skills]

- 2. Data Preparation & Utilization > 2.1 Strategic Utilization of Data and AI > Data / AI Utilization Strategy Design

- 2. Data Preparation & Utilization > 2.1 Strategic Utilization of Data and AI > AI Implementation and Operation

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  ==== Standards & Protocols

- AGENTS.md - An open standard for defining and running AI agents
- Agent Skills - A simple, open format for giving agents new capabilities and expertise
- Model Context Protocol (MCP) - An open-source standard for connecting AI applications to external systems, enabling them to access data sources, tools, and workflows
- A2A Protocol - A protocol for enabling bidirectional communication between web applications and AI agents
- Agent Name Service (ANS) - A secure, DNS-inspired framework for AI agent discovery that leverages Public Key Infrastructure (PKI) for identity verification, structured JSON schemas for communication, and a protocol adapter layer supporting A2A, MCP, and ACP protocols
- GitAgent - A framework-agnostic standard that allows you to define an AI agent as a set of version-controlled files within a Git repository
- AG-UI (Agent–User Interaction Protocol) - An open, lightweight, event-based protocol that standardizes how AI agents connect to user-facing applications

Agentic Patterns & Techniques

- ReAct Prompting - A prompting technique synergizing reasoning and acting in language models
  - Reason, Act, Thought, Observation
- Recursive Language Models - An inference strategy where language models (LMs) can decompose and recursively interact with input context of unbounded length
- Effective Context Engineering for AI Agents - The set of strategies for curating and maintaining the optimal set of tokens (information) during LLM inference, including all the other information that may land there outside of the prompts

Agent Orchestration & Frameworks

- Orchestration Frameworks
  - Agno - A multi-agent framework, runtime and control plane
  - crewAI - An open-source, multi-agent orchestration framework that empowers developers to orchestrate high-performing AI agents with ease and scale
  - Deep Agents - The easiest way to start building agents and applications powered by LLMs—with built-in capabilities for task planning, file systems for context management, subagent-spawning, and long-term memory
  - LangGraph - A library for building stateful, multi-actor applications with LLMs by creating cyclic graphs for agent runtimes

  - Mastra - An all-in-one, open-source TypeScript framework for building, iterating, and deploying AI agents with built-in support for workflows, RAG, memory, and observability
  - Microsoft Agent Framework - A resource for building robust, future-proof Agentic AI solutions that evolve with technological advancements
  - Microsoft 365 Agents SDK - A comprehensive framework for building full-stack, multi-channel agents that operate seamlessly across Microsoft 365 Copilot, Teams, third-party platforms, custom applications, and websites
- Application Frameworks
  - Chainlit - An open-source Python package to build production ready Conversational AI
  - DSPy - A declarative framework for building modular AI software that allows for fast iteration on structured code and offers algorithms to compile AI programs into effective prompts and weights for language models
  - Genkit - The AI framework for building full-stack applications with integrated support for agents, RAG, and tool use
  - LangChain - A framework for developing applications powered by large language models
  - LlamaIndex - A developer-first agent framework that rapidly accelerates time-to-production of GenAI applications with trusted low and high-level abstractions
  - PydanticAI - A Python agent framework for building production-grade applications with Generative AI, emphasizing type safety and structured outputs

Agent Development Kits (ADK)

- Agent Package Manager (APM) - An open-source dependency manager for AI agents that provides a single source of truth for skills, prompts, and instructions
- Agent Development Kit (ADK) - A flexible and modular framework for developing and deploying AI agents
- Claude Agent SDK - The Agent SDK gives you the same tools, agent loop, and context management that power Claude Code, programmable in Python and TypeScript
- Claude Agent Skills - The modular capabilities that extend an agent's functionality by packaging instructions, metadata, and optional resources
- Fantasy - A Go library for building AI agents with multiple providers and models through a single API
- Microsoft 365 Agents Toolkit - A suite of tools for building enterprise-ready agents and apps that work across Microsoft 365 Copilot, Teams, Office, web, and other third-party messaging channels
- OpenAI Agents SDK - A library for building agentic applications where models can use additional context and tools, hand off to specialized agents, and stream results

Supporting Services & Platforms

- Agent Platforms & Services
  - Foundry Agent Service - A platform to securely design, deploy, and scale AI agents with governance and observability for enterprise transformation
  - Moltbook - A social network for AI agents where AI agents share, discuss, and upvote
- Interoperability
  - FastMCP - A Pythonic framework for building Model Context Protocol (MCP) servers and clients
- Pre-built Agents & Collections
  - agency-agents - A growing collection of meticulously crafted AI agent personalities designed to act as specialized experts with unique voices, proven workflows, and measurable deliverables
- Memory Systems
  - Mem0 - An AI memory layer for LLM applications that aims to provide personalized AI experiences
  - Graphiti - An open-source Python framework for building temporally-aware context graphs
  - Hindsight - A memory system designed specifically for AI agents that enables them to retain, recall, and reason about information across multiple sessions using multi-strategy retrieval and automatic knowledge consolidation
- Search & Data Extraction
  - Firecrawl - An API service that takes a URL, crawls it, and converts it into clean markdown or structured data
  - Tavily Search - A search engine optimized for LLMs, aimed at efficient, quick and persistent search results
  - SWIRL AI Search - A Federated AI Search solution that connects to over 100 enterprise platforms, providing real-time visibility across data and document silos without requiring costly data transformations or migrations
- Security Tools
  - skill-scanner - A best-effort security scanner for AI Agent Skills that detects prompt injection, data exfiltration, and malicious code patterns
  - ClawShell - The Runtime Security Layer for OpenClaw, the essential safety harness for PII & sensitive credentials protection

MLOps & LLMOps

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > SRE Process

- 2. Data Preparation & Utilization > 2.1 Strategic Utilization of Data and AI > AI Implementation and Operation

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  ==== ML Lifecycle & MLOps Platforms

- ML Lifecycle Tools
  - DVC - Open-source Data Version Control for machine learning projects
  - CML - An open-source tool for implementing continuous integration & delivery (CI/CD) in machine learning projects
  - MLFlow - An open source platform to manage the ML lifecycle, including experimentation, reproducibility, deployment, and a central model registry
  - KubeFlow - The Machine Learning Toolkit for Kubernetes, dedicated to making deployments of ML workflows on Kubernetes simple, portable and scalable
  - Weights & Biases - The AI developer platform to build AI agents, applications, and models with confidence
  - ZenML - An open-source framework for orchestration, versioning, and governance from training pipelines to agent evals, local to Kubernetes
  - BentoML - An open-source framework to deploy any model anywhere, with tailored optimization, efficient scaling, and streamlined operations
- Managed MLOps Platforms
  - Microsoft Foundry - A unified, interoperable platform for building, optimizing, and governing AI apps and agents that understand business context and deliver business impact
  - Vertex AI - A machine learning (ML) platform for training and deploying ML models and AI applications
  - Nebius - A specialized AI cloud platform offering purpose-built infrastructure for AI and machine learning workloads
  - Amazon SageMaker - A fully managed service bringing together data, analytics, and AI to build, train, and deploy models at scale

LLM Serving & Runtimes

- Local LLM Runtimes
  - LM Studio - A desktop app for developing and experimenting with LLMs locally on your computer
  - LocalAI - The free, Open Source OpenAI alternative
  - Ollama - A tool designed for deploying and managing large language models (LLMs) locally
  - llama.cpp - A dependency-free C/C++ implementation for running LLM inference across hardware from Apple Silicon to NVIDIA GPUs

  - Jan - An open-source ChatGPT alternative that runs AI models locally on your computer

- Production Serving Engines
  - vLLM - A high-throughput and memory-efficient inference and serving engine for Large Language Models (LLMs)
  - Hugging Face TGI - A Rust, Python and gRPC server for text generation inference, used in production to power Hugging Chat and the Inference API
  - SGLang - A high-performance serving framework for large language models and multimodal models
  - KServe - A standardized distributed generative and predictive AI inference platform for scalable, multi-framework deployment on Kubernetes
  - Modular MAX - A unified AI inference platform delivering full optimizations from GPU kernel to API endpoint across diverse hardware

LLMOps & Observability

- Managed Model Services
  - Amazon Bedrock - A fully managed service offering a choice of high-performing foundation models
    - Amazon Bedrock Agents - A service that uses the reasoning of foundation models, APIs, and data to break down user requests, gather relevant information, and efficiently complete tasks
- Agent Observability
  - Mission Control - A centralized operational control plane to manage, monitor, and coordinate fleets of AI agents
- LLM Observability & Evals
  - Langfuse - An open source LLM engineering platform providing traces, evals, prompt management, and metrics to debug and improve LLM applications
  - OpenLIT - An open-source, OpenTelemetry-native tool for LLM and GenAI observability
  - LangSmith - A unified DevOps platform for developing, collaborating, testing, deploying, and monitoring LLM applications
  - Helicone - An open-source LLM observability platform built for developers to monitor and optimize their generative AI applications
  - Arize Phoenix - An open-source AI observability and evaluation platform for LLMs
  - Braintrust - The enterprise AI platform that provides an evaluation and observability platform for developers building with LLMs
  - Ragas - A library that helps you move from vibe checks to systematic evaluation loops for your AI applications
  - DeepEval - The LLM evaluation framework with research-backed metrics and pytest-

native evaluations that run in CI/CD

07 - Fundamental Developer Skills

Software Development Methods

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Software Development Process
- 5. Personal Skill > 5.2 Conceptual Skill > Adaptability

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==== Agile Development

- Agile software development - An umbrella term for approaches to developing software that reflect the values and principles agreed upon by The Agile Alliance
  - Agile Manifesto - A document that proclaims better ways of developing software by valuing individuals and interactions over processes and tools, working software over comprehensive documentation, customer collaboration over contract negotiation, and responding to change over following a plan
  - Software prototyping - The activity of creating prototypes of software applications, i.e., incomplete versions of the software program being developed
  - Minimum viable product - A version of a product with just enough features to be usable by early customers who can then provide feedback for future product development
  - User story - An informal, natural language description of features of a software system
    - Card, Conversation, Confirmation - A practice where the Card is a token representing the requirement, the Conversation is where details are teased out, and the Confirmation is the acceptance test for the story
  - INVEST of PBI - A mnemonic created by Bill Wake as a reminder of the characteristics of a good quality Product Backlog Item (PBI)
    - Independent: The PBI should be self-contained
    - Negotiable: Draft PBIs are not explicit contracts and should leave space for discussion
    - Valuable: A PBI must deliver value to the stakeholders
    - Estimable: You must always be able to estimate the size of a PBI
    - Small: PBIs should not be so big as to become impossible to plan/task/order within a level of accuracy
    - Testable: The PBI or its related description must provide the necessary information to make test development possible
- Key Methodologies

    - Extreme Programming - A software development methodology which is intended to improve software quality and responsiveness to changing customer requirements
    - Scrum - A framework within which people can address complex adaptive problems, while productively and creatively delivering products of the highest possible value
    - Acceptance test-driven development - A development methodology based on communication between the business customers, the developers, and the testers
        · Three Amigos - A meeting where the product owner, developer, and quality tester come together to establish clarity on the scope of the project
    - Behavior driven development - An agile software development process that encourages collaboration among developers, quality assurance testers, and customer representatives in a software project
        · Specification by example - A collaborative approach to defining requirements and business-oriented functional tests for software products based on capturing and illustrating requirements using realistic examples instead of abstract statements

- Key Practices
    - Refactoring - A disciplined technique for restructuring an existing body of code, altering its internal structure without changing its external behavior
        · Software rot - The tendency for software to deteriorate in quality, performance, or usefulness over time
        · Technical debt - A concept in software development that reflects the implied cost of additional rework caused by choosing an easy (limited) solution now instead of using a better approach that would take longer
            · Technical Debt Ratio - A metric used to measure the cost of fixing the existing technical debt in a codebase compared to the cost of developing the entire codebase from scratch
    - Test driven development - A software development process relying on software requirements being converted to test cases before software is fully developed, and tracking all software development by repeatedly testing the software against all test cases

- Tools for ATDD/BDD
    - Gauge - A free and open source test automation framework that takes the pain out of writing and maintaining acceptance tests
    - Cucumber - A tool that supports Behaviour-Driven Development (BDD) by reading executable specifications written in plain text and validating that the software does what those specifications say
        · Gherkin Syntax - A set of grammar rules that makes plain text structured enough for Cucumber to understand
        · cucumber-ruby - The Ruby implementation of Cucumber
    - RSpec - A testing tool for the Ruby programming language, created for behavior-driven development (BDD)
    - Behave - A tool for behavior-driven development (BDD) in Python, using tests written

in a natural language style, backed up by Python code

Lean Development

- Lean software development - A translation of lean manufacturing principles and practices to the software development domain
  - Continual improvement process - An ongoing effort to improve products, services, or processes
  - OODA loop - A four-step approach to decision-making that focuses on filtering available information, putting it in context and quickly making the most appropriate decision while also understanding that changes can be made as more data becomes available
- Lean manufacturing - A production method aimed primarily at reducing times within the production system as well as response times from suppliers and to customers
  - The 7 Wastes: The activities that add no value for the customer
  - Value-stream mapping - A lean-management method for analyzing the current state and designing a future state for the series of events that take a product or service from the beginning of the specific process until it reaches the customer
- Toyota Production System - An integrated socio-technical system, developed by Toyota, that comprises its management philosophy and practices
  - Kanban - A lean method to manage and improve work across human systems
  - Kaizen - A philosophy that focuses on continuous, incremental improvement of all functions and involves all employees from the CEO to the assembly line workers
  - Autonomation - The practice of designing equipment to partially automate a process and to automatically stop when a problem is detected, allowing operators to fix the issue immediately
  - Heijunka - A method for smoothing out production by leveling both the volume and the product mix
  - Genchi Genbutsu - A principle that suggests that to truly understand a situation, one needs to go to the "real place" where the work is done, observe the process, and verify the facts for themselves
  - Andon (manufacturing) - A visual management system used to indicate the status of a production line
  - Muda (Japanese term) - A key concept in lean process management as one of the three types of deviation from optimal allocation of resources, meaning futility, uselessness, or wastefulness
- Theory of Constraints - A management paradigm that views any manageable system as being limited in achieving more of its goals by a very small number of constraints

DevOps & Engineering Productivity

- Concepts

    - CALMS framework - A conceptual model for approaching DevOps that stands for Culture, Automation, Lean, Measurement, and Sharing
- Cultural & Organizational Foundations
    - Generative organizational culture - A type of culture characterized by a high degree of trust and cooperation, a shared sense of responsibility for the mission, and a focus on learning and continuous improvement
- Technical Practices
    - Feature Toggles - A powerful technique, allowing teams to modify system behavior without changing code
    - Blue-Green Deployment - A technique that reduces downtime and risk by running two identical production environments called Blue and Green
    - Canary Release - A technique to reduce the risk of introducing a new software version in production by slowly rolling out the change to a small subset of users before rolling it out to the entire infrastructure
    - Everything as code - A software development practice that seeks to apply the same principles of version control, testing, and deployment to enhance maintainability and scalability of all aspects of the development lifecycle, including networking infrastructure, documentation, and configuration

Release Automation

- semantic-release - A fully automated version management and package publishing tool that determines the next version number, generates release notes, and publishes the package based on formalized commit messages
- Release Please - A tool that automates changelog generation, the creation of GitHub releases, and version bumps for your projects based on Conventional Commits
- GoReleaser - A release automation tool for Go projects
- Changesets - A tool to manage versioning and changelogs with a focus on monorepos

Release Conventions & Standards

- keep a changelog - A file which contains a curated, chronologically ordered list of notable changes for each version of a project
- Conventional Commits - A lightweight convention on top of commit messages that provides an easy set of rules for creating an explicit commit history
- Semantic Versioning - A simple set of rules and requirements that dictate how version numbers are assigned and incremented
- CalVer - A versioning convention based on your project's release calendar, instead of arbitrary numbers

The Open Ecosystem

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Team Development

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  ==== Open Source

- Open Source Initiative - A non-profit organization dedicated to promoting and protecting open source software and communities
- Major Public Licenses
  - MIT - A permissive software license originating at the Massachusetts Institute of Technology (MIT) in the late 1980s
  - BSD - A family of permissive free software licenses, imposing minimal restrictions on the use and distribution of covered software
  - Apache - A permissive free software license written by the Apache Software Foundation (ASF), allowing users to use, distribute, and modify software without concern for royalties
  - GPL - A series of widely used free software licenses, or copyleft licenses, that guarantee end users the freedom to run, study, share, and modify the software
  - LGPL - A free-software license published by the Free Software Foundation (FSF) that allows developers and companies to use and integrate a software component released under it into their own (even proprietary) software without being required to release the source code of their own components
  - AGPL - A free, copyleft license for software and other kinds of works, specifically designed to ensure that if you run a modified program on a server and let other users communicate with it there, your server must also allow them to download the source code corresponding to the modified version running there
  - SSPL - A strong copyleft software license that mandates that any entity offering the licensed software as a service must release the complete source code of the entire service
- Principles & Adages
  - Linus’s law - The assertion that 'given enough eyeballs, all bugs are shallow', which is a key principle in open source development
- Source Repositories
  - GitHub - The AI-powered developer platform to build, scale, and deliver secure software
  - GitLab.com - The DevSecOps Platform that empowers organizations to maximize the overall return on software development
- Package Registries
  - CTAN - The Comprehensive TEX Archive Network

  - CPAN - The Comprehensive Perl Archive Network
  - CRAN - The Comprehensive R Archive Network
  - PyPI - A repository of software for the Python programming language
  - RubyGems.org - The Ruby community's gem hosting service
  - npm Registry - The world's largest software registry
  - JSR - The open-source package registry for modern JavaScript and TypeScript
  - pkg.go.dev - Your source for information about Go packages and modules
  - crates.io - The Rust community's crate registry
  - LuaRocks - The package manager for Lua modules
  - Hackage - The Haskell community's central package archive of open source software
    - Stackage - A curated set of packages from Hackage
  - NuGet Gallery - The package manager for .NET
  - Maven Central - The World's Largest and Oldest Component Repository
  - ConanCenter - The central repository where you can find all the open source packages created by the community
  - Anaconda Hub - The Hub for Data Science and AI Collaboration

Open Data

- Tools and Licenses
  - Creative Commons - A nonprofit organization that helps overcome legal obstacles to the sharing of knowledge and creativity to address the world's pressing challenges
  - Open Data Commons - The home of a set of legal tools and licenses to help you publish, provide and use open data
- Open Data Registries
  - Hugging Face Hub - A platform with over 900k models, 200k datasets, and 300k demos in which people can easily collaborate in their ML workflows
  - Data.gov - The home of the U.S. Government's open data
  - Kaggle - The world's largest data science community with powerful tools and resources to help you achieve your data science goals
  - Registry of Open Data on AWS - A service that makes it easy for people to find datasets that are publicly available through AWS services
  - OpenML - An open, collaborative, frictionless, and automated machine learning environment
  - OpenStreetMap - A map of the world, created by people like you and free to use under an open license
- Data Search Engines
  - Google Dataset search - A search engine that enables users to find datasets stored

across thousands of repositories on the Web

Community & Governance

- Umbrella Open Source Foundations
  - Linux Foundation - A non-profit organization that supports, protects, and standardizes Linux by providing a neutral, trusted hub for developers to code, manage, and scale open technology projects
  - Apache Software Foundation - A nonprofit corporation to support Apache software projects, including the Apache HTTP Server
  - Eclipse Foundation - A provider of a business-friendly environment for open source software collaboration and innovation for a global community of individuals and organizations
- Technology-Specific Foundations
  - OpenJS Foundation - The neutral home for more than 40 open source projects, including Appium, Dojo, jQuery, Node.js, and webpack
  - Rust Foundation - An independent non-profit organization dedicated to stewarding and growing the Rust programming language and ecosystem
  - Python Software Foundation - The charitable organization behind the Python programming language
  - PyTorch Foundation - A community-driven hub for open-source AI
- Cloud & AI
  - Cloud Native Computing Foundation - An open source software foundation dedicated to making cloud native computing universal and sustainable
  - Agentic AI Foundation (AAIF) - A neutral, open foundation to ensure this critical capability evolves transparently, collaboratively, and in ways that advance the adoption of leading open source AI projects
- Web & Data Standards
  - World Wide Web Consortium - An international community that develops open standards to ensure the long-term growth of the Web
  - WHATWG - A community of people interested in evolving HTML and related technologies
  - The Open Group - A global consortium that enables the achievement of business objectives through technology standards
- Ethical & Digital Rights
  - Free Software Foundation - A nonprofit with a worldwide mission to promote computer user freedom
- Community Governance & Codes of Conduct
  - Debian Constitution - A document that describes the structure of organisation for decision-making in the Debian Project

  - Ubuntu Code of Conduct - A set of guidelines that covers behavior as a member of the Ubuntu Community
  - Mozilla Community Participation Guidelines - A set of guidelines that outline expectations for participants within the Mozilla community
  - Contributor Covenant - A code of conduct for contributors to free/open source software projects, created by Coraline Ada Ehmke

Shell & Terminal

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Computer Science
- 3. Technology > 3.1 Software Development > Team Development

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==== Bash & Other Shells

- Bash - An sh-compatible shell that incorporates useful features from the Korn shell (ksh) and the C shell (csh)
  - Line editing - The basic features of the GNU command line editing interface
  - History - The history expansion features of Bash
  - Shell expansions - The process performed on the command line after it has been split into words
  - Pipelines - A sequence of one or more commands separated by one of the control operators ‘|’ or ‘|&’
  - Built-in commands - The commands that are executed within the shell process itself, without forking a new process
  - Special variables - A list of shell variables that are set or used by the shell
  - Built-in job control - The ability to selectively stop (suspend) the execution of processes and continue (resume) their execution at a later time
- Zsh - A shell designed for interactive use, although it is also a powerful scripting language
- fish-shell - A smart and user-friendly command line shell for Linux, macOS, and the rest of the family
- PowerShell - A cross-platform task automation solution made up of a command-line shell, a scripting language, and a configuration management framework
- nushell - A new type of shell

Shell Utilities

- General Shell Utilities
  - coreutils = A package of GNU software containing many of the basic tools, such as

cat, ls, and rm, needed for Unix-like operating systems
    - GNU parallel - A shell tool for executing jobs in parallel using one or more computers
    - rlwrap - A readline wrapper
    - bash-completion - A collection of programmable completion functions for bash
    - direnv - An extension for your shell that can load and unload environment variables depending on the current directory
    - zoxide - A smarter cd command
    - Atuin - A tool that replaces your existing shell history with a SQLite database, records additional context for your commands, and optionally syncs your shell history between all of your machines
    - wttr.in - A console-oriented weather forecast service that delivers weather information through command-line tools like curl, httpie, or wget
- Search Tools
    - findutils - The basic directory searching utilities of the GNU operating system
    - fzf - A general-purpose command-line fuzzy finder
    - fd - A simple, fast and user-friendly alternative to find
    - grep - A command-line utility for searching plain-text data sets for lines that match a regular expression
    - ripgrep - A line-oriented search tool that recursively searches the current directory for a regex pattern
    - silversearcher-ag - A code-searching tool similar to ack, but faster
- Shell Frameworks & Customization
    - starship - The minimal, blazing-fast, and infinitely customizable prompt for any shell!
    - oh-my-bash - An open source, community-driven framework for managing your BASH configuration
    - oh-my-zsh - A delightful, open source, community-driven framework for managing your Zsh configuration
    - Zim Framework - The Zsh configuration framework with blazing speed and modular extensions
    - Powerlevel10k - A theme for Zsh
    - Pure - A pretty, minimal and fast ZSH prompt
- Shell Tutorials
    - LinuxCommand.com - A site containing a book and other material designed to help you learn how to use the Linux command line

Terminal Emulators

- Terminal Emulators - A computer program that emulates a video terminal within some other display architecture

  - WaveTerm - An open-source, cross-platform, AI-integrated terminal
  - kitty - The fast, feature-rich, GPU based terminal emulator
  - Rio Terminal - A modern terminal for the 21st century
  - Alacritty - A modern terminal emulator that comes with sensible defaults, but allows for extensive configuration
  - Terminator - A terminal emulator like xterm, gnome-terminal, konsole, etc.
  - Windows Terminal - The new Windows Terminal and the original Windows console host
  - Mintty - A terminal emulator for Cygwin, MSYS or Msys2, and derived projects, and for WSL
  - xterm - A terminal emulator for the X Window System
  - wterm - A terminal emulator for the web that renders directly to the DOM using a Zig+WASM core, enabling native browser text selection, copy/paste, and accessibility
- Technologies & Protocols
  - Pseudoterminal - A pair of pseudo-devices that provides a terminal-like interface used by programs to emulate a terminal
  - ANSI escape code - A standard for in-band signaling to control the cursor location, color, font styling, and other options on video text terminals
  - kitty keyboard protocol - A protocol for terminals to send keyboard events to applications running in them
  - iTerm2 image protocol - A custom escape code to display images inline in the terminal
- Terminal Fonts
  - Nerd Fonts - A project that patches developer targeted fonts with a high number of glyphs
  - Share Tech Mono - A monospaced sans serif, based on the Share family
  - Cascadia Code - A fun, new monospaced font that includes programming ligatures

Terminal Utilities

- Multiplexers & Session Management
  - screen - A full-screen window manager that multiplexes a physical terminal between several processes
  - tmux - A terminal multiplexer
  - byobu - A GPLv3 open source text-based window manager and terminal multiplexer
  - zellij - A terminal workspace with batteries included
  - asciinema - A free and open source solution for recording terminal sessions and sharing them on the web

  - ttyd - A simple command-line tool for sharing terminal over the web
- Console File Managers
  - midnight commander - A visual file manager
  - ranger - A VIM-inspired filemanager for the console
  - superfile - A very fancy and modern terminal file manager

Linux or Unix-like environments on Windows

- winpty - A Windows software package providing a Unix-like VT100 console interface for Windows console programs
- WSL - A feature of Windows that enables you to run a GNU/Linux environment on your Windows machine without the need for a separate virtual machine or dual booting
  - WSLg - A project that enables support for running Linux GUI applications (X11 and Wayland) on Windows in a fully integrated desktop experience
- Git for Windows - A lightweight, native set of tools that bring the full feature set of the Git SCM to Windows
- MSYS2 - A collection of tools and libraries providing you with an easy-to-use environment for building, installing and running native Windows software

Version Control System

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Team Development

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- Concepts
  - Distributed Version Control - A form of version control where the complete codebase, including its full history, is mirrored on every developer’s computer
- Core VCS & Clients
  - Git - A free and open source distributed version control system designed to handle everything from small to very large projects with speed and efficiency
    - local repository, remote repository
    - branch, tag, worktree
    - push, pull, fetch, rebase, reset, stash
    - staging, commit
  - Jujutsu (jj) - A Git-compatible VCS that is both simple and powerful
  - TortoiseGit - A Windows Shell Interface to Git and based on TortoiseSVN
  - git lfs - An open source Git extension for versioning large files
- Terminal & UI Tools

  - Informative git prompt for bash and fish - A bash prompt that displays information about the current git repository
  - lazygit - A simple terminal UI for git commands
  - giff - A terminal-based Git diff viewer with interactive rebase capabilities that allows you to view and manage changes between branches
  - Git Interactive Rebase Tool - An improved sequence editor for Git
- History & Maintenance Tools
  - BFG Repo-Cleaner - A simpler, faster alternative to git-filter-branch for cleansing bad data out of your Git repository history
  - git filter-repo - A versatile tool for rewriting history
  - degit - Straightforward project scaffolding
- Commit & Changelog Tooling
  - Git Lint - A command line interface for linting Git commits by ensuring you maintain a clean, easy to read, debuggable, and maintainable project history
  - commitlint - A tool that helps your team adhere to a commit convention by linting commit messages
  - git cliff - A highly customizable changelog generator
- Hook Management
  - pre-commit - A framework for managing and maintaining multi-language pre-commit hooks
  - Lefthook - A fast, polyglot Git hooks manager for any type of project

Git Hosting Services

- GitLab SCM - The single source of truth for collaborating on code and projects
  - GitLab CLI - An open source tool that brings GitLab to your terminal, next to where you are already working with git and your code
- Gitea - A painless self-hosted all-in-one software development service, including Git hosting, code review, team collaboration, package registry and CI/CD
- Codeberg - A community-led effort that provides Git hosting and other services for free and open source projects
- Forgejo - A self-hosted lightweight software forge
- Soft Serve - A tasty, self-hostable Git server for the command line
- Azure Repos - A set of version control tools that you can use to manage your code
- GitHub - The AI-powered developer platform to build, scale, and deliver secure software
  - GitHub CLI - An open source tool that brings pull requests, issues, GitHub Actions, and other GitHub features to your terminal, so you can do all your work in one place

Branching Models

- Trunk Based Development - A source-control branching model, where developers collaborate on code in a single branch called 'trunk', resist any pressure to create other long-lived development branches by employing documented techniques
- GitHub Flow - A lightweight, branch-based workflow designed for teams that deploy frequently
- GitLab Flow - A simpler alternative to GitFlow that combines feature driven development and feature branches with issue tracking

Code Review

- Google Engineering Practices Documentation - A comprehensive guide to Google's code review processes and policies for both reviewers and change authors
- Conventional Comments - A standard that provides a structured format for code review feedback to improve clarity, reduce misunderstandings, and make comments machine-readable
- Danger - A tool to automate team norms in code review

Integrated Development Environment (IDE)

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Team Development

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- GUI-based
  - Visual Studio Code - A lightweight but powerful source code editor which runs on your desktop and is available for Windows, macOS and Linux
    - Awesome VS Code - A curated list of delightful VS Code packages and resources
    - GitLens - An extension that supercharges the Git capabilities built into Visual Studio Code
    - Git Graph - An extension to view a Git Graph of your repository, and perform Git actions from the graph
  - AI Assistance Plugins
    - GitHub Copilot - The AI pair programmer that helps you write code faster and with less work
    - Gemini Code Assist - An AI-powered assistant for the entire development lifecycle
    - Amazon Q Developer - The most capable generative AI-powered assistant for software development
    - Cline - An open source AI coding agent that brings frontier AI models directly to your VS Code editor

    - AI-integrated IDEs
        - Cursor - An AI-native fork of VS Code designed for seamless, agentic integration with proprietary and frontier models
        - Winfsurf - Where the work of developers and AI truly flow together, allowing for a coding experience that feels like literal magic
        - Zed - A next-generation code editor designed for high-performance collaboration with humans and AI
- Web-based
    - code-server - A VS Code instance running on a remote server, accessible through any web browser
    - Replit - A platform to turn ideas into apps in minutes — no coding needed
- Terminal-based
    - Vim - A highly configurable text editor built to make creating and changing any kind of text very efficient
        - motion and operators - The commands that move the cursor and the commands used to delete or change text
        - vim-plug - The de-facto standard plugin manager for Vim
        - NERDTree - A tree explorer plugin for vim
    - Neovim - Hyperextensible Vim-based text editor
        - LazyVim - A Neovim setup powered by ¬ lazy.nvim to make it easy to customize and extend your config
            - lazy.nvim - A modern plugin manager for Neovim
        - NvChad - A blazing fast Neovim config providing solid defaults and a beautiful UI
        - neo-tree.nvim - A Neovim plugin to manage the file system and other tree like structures
        - colorful-winsep.nvim - A colorful window separator for Neovim
        - mason.nvim - A Neovim plugin that allows you to easily manage external editor tooling such as LSP servers, DAP servers, linters, and formatters through a single interface
        - telescope.nvim - A highly extendable fuzzy finder over lists
        - flash.nvim - A plugin that helps you navigate your code with search labels, enhanced character motions and Treesitter integration
        - nvim-llama - A simple interface to Ollama for Neovim
    - Helix - A modal editor, meaning it has different modes for different tasks
    - GNU Emacs - An extensible, customizable, free/libre text editor — and more
        - MELPA - Milkypostman’s Emacs Lisp Package Archive
        - doomemacs - An Emacs framework for the stubborn martian hacker

        - neotree - A tree explorer for Emacs
        - Treemacs - A tree layout file explorer for Emacs
        - Spacemacs - A community-driven Emacs distribution
    - Tutorials and Cheet Sheets
        - OpenVim - An interactive Vim tutorial
        - Vim Adventures - An online game based on VIM's keyboard shortcuts
        - Vim Cheet Sheet - A quick reference guide for Vim commands

Language Servers

- LSP - The protocol used between an editor or IDE and a language server that provides language features like auto complete, go to definition, find all references etc.
- pyright - A static type checker and language server for Python
    - Pylance - An extension that works alongside the Python extension in Visual Studio Code to provide performant language support
- Ruby LSP - An opinionated language server for Ruby
- TypeScript Language Server - A standalone TypeScript and JavaScript language server
- Gopls - The official language server for the Go language
- rust-analyzer - A language server for the Rust programming language
- Eclipse JDT Language Server - A Java language server based on the Eclipse JDT

Code Quality & Refactoring

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Team Development

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- Concepts
    - SQALE method - A method to support the evaluation of the quality of a software source code
    - Cyclomatic complexity - A software metric used to indicate the complexity of a program
- Code Metrics Tools
    - scc - A tool that counts lines of code in many programming languages
    - cloc - A tool that counts blank lines, comment lines, and physical lines of source code in many programming languages

Analysis Platform

- SonarQube Server - An on-premise analysis tool designed to detect coding issues in 30+ languages, frameworks, and IaC platform
- GitLab Code Coverage - A report that shows the percentage of your code that is covered by tests
- GitLab Code Quality - A feature that uses CodeClimate Engines to provide code quality analysis for your projects

Formatters

- EditorConfig - A file format for defining coding styles and a collection of text editor plugins that enable editors to read the file format and adhere to defined styles
- Prettier - An opinionated code formatter
- Ruff - An extremely fast Python linter and code formatter, written in Rust
- Biome - A toolchain of the web that provides a fast formatter and performant linter for JavaScript, TypeScript, JSX, JSON, HTML, CSS, and GraphQL

Linters

- ESLint - An open source project that helps you find and fix problems with your JavaScript code
- JSHint - A Static Code Analysis Tool for JavaScript
- Biome - A toolchain of the web that provides a fast formatter and performant linter for JavaScript, TypeScript, JSX, JSON, HTML, CSS, and GraphQL
- Pylint - A static code analyser for Python 2 or 3
- Ruff - An extremely fast Python linter and code formatter, written in Rust
- Staticcheck - A state of the art linter for the Go programming language
- revive - Fast & extensible static code analysis framework for Go
- golangci-lint - A fast linters runner for Go
- RuboCop - A Ruby static code analyzer (a.k.a linter) and code formatter
- Rust Clippy - A collection of lints to catch common mistakes and improve your Rust code
- PSScriptAnalyzer - A static code checker for PowerShell modules and scripts
- ShellCheck - A GPLv3 tool that gives warnings and suggestions for bash/sh shell scripts
- Stylelint - A mighty CSS linter that helps you avoid errors and enforce conventions
- vacuum - An ultra-super-fast, lightweight OpenAPI linter and quality checking tool
- yamllint - A linter for YAML files
- ls-lint - An extremely fast file and directory name linter

Coding style guides

- Google Style Guides - A collection of documents that provide a set of conventions for writing source code in various programming languages
- Style Guide for Python - A document that gives coding conventions for the Python code comprising the standard library in the main Python distribution
- Ruby Style Guide - A community-driven style guide for the Ruby programming language

Developer AI & Productivity

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Team Development

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  ==== AI Productivity Tools

- Mods - A simple tool that helps you write programs with the assistance of AI
- gptcli - A command-line interface for ChatGPT
- ShellGPT - A command-line productivity tool powered by AI large language models (LLM)
- OpenCommit - Auto-generate meaningful commits in a second
- AI Commits - A CLI that writes your git commit messages for you with AI
- lootbox - A CLI which is inspired by "Code Mode" - LLMs write TypeScript code to call APIs rather than using tool invocation

Development Agents

- CLI Coding Agents
  - Claude Code - An agentic coding tool that reads your codebase, edits files, runs commands, and integrates with development tools
    - Plan Mode - A mode that instructs Claude to create a plan by analyzing the codebase with read-only operations, perfect for exploring codebases, planning complex changes, or reviewing code safely
    - Hooks - The user-defined shell commands or LLM prompts that execute automatically at specific points in the agent’s lifecycle
    - Subagents - The specialized AI assistants that handle specific types of tasks, running in their own context with custom prompts and tool access
    - Sandboxing - A feature that provides filesystem and network isolation for safer, more autonomous agent execution, using OS-level primitives to enforce these isolations and reduce constant permission prompts
    - Auto-memory - A feature that allows the agent to automatically accumulate knowledge across sessions by saving notes on build commands, debugging

insights, architecture notes, and user preferences without manual intervention

- Gemini CLI - An open-source AI agent that brings the power of Gemini directly into your terminal
  - Conductor - The official project management tool for Gemini CLI
  - Sandboxing - A feature that isolates potentially dangerous operations from your host system, providing a security barrier between AI operations and your environment, using macOS Seatbelt or container-based methods for isolation
- Antigravity CLI - A terminal-based AI coding agent that understands codebases, makes edits with permission, and executes commands directly from the terminal
- Aider - An AI pair programming tool in your terminal that lets you start a new project or build on your existing codebase
- Letta Code - A memory-first coding agent that lives in your terminal
- Deep Agents CLI - A terminal coding agent built on the Deep Agents SDK
- OpenCode.ai - An open-source AI coding agent for the terminal that provides an interactive TUI to help you understand, edit, and ship code within real repositories
- OpenAI Codex - A lightweight coding agent that runs in your terminal, providing a local coding assistant
- Kimi Code - A CLI coding agent by Moonshot AI engineered to drop into any dev workflow, supporting codebase analysis, file operations, web search, and parallel sub-agent task handling, powered by the kimi-k2.6 model
- Crush - The glamourous AI coding agent for your favourite terminal ¬
- ForgeCode - A ZSH-integrated coding harness with a multi-agent architecture for research, planning, and execution, supporting multiple LLM providers and ranking at the top of Terminal-Bench

• Desktop Coding Agents

- goose - A local AI agent that automates engineering tasks seamlessly
- Open Interpreter - An open-source desktop agent that lets you work alongside agents that can read, edit, and create documents on your computer
- Agent Zero - An open-source personal AI agent that uses a dynamic toolset to solve complex tasks by writing and executing code, managing its own computer environment, and learning from its actions
- AionUI - A Cowork app for AI coding agents with document generation capabilities

• Autonomous Coding Agents

- SWE-agent - A tool for fixing bugs and issues in GitHub repositories, powered by a family of language models
- mini-swe-agent - A smaller, more accessible version of SWE-agent
- Devin - An autonomous AI software engineer that can handle complex engineering tasks unassisted within its own sandboxed environment
- Jules - An Autonomous Coding Agent

    - Replit Agent - The first developer agent that can learn and work alongside you in your IDE

Supporting Tools & Infrastructure

- Platforms
    - OpenHands - A platform for software development agents powered by AI
    - Port - An agentic developer portal to build autonomous workflows to accelerate every aspect of engineering
    - Antigravity - An agentic development platform
- Agent Orchestration
    - TAKT (TAKT Agent Koordination Topology) - An open-source framework designed to orchestrate and manage AI coding agents using structured, YAML-defined workflows
    - KIRA - An agent framework for terminal-based AI tasks that leverages native tool calling, multimodal input, and marker-based completion verification to achieve state-of-the-art performance on Terminal-Bench
- Benchmarks
    - SWE-bench - A benchmark for evaluating large language models on real world software issues collected from GitHub
    - Terminal-Bench - A collection of harbor-native benchmark tasks for quantifying AI agents' terminal mastery, covering software engineering, machine learning, security, and data science
- Context Providers
    - Context7 - An AI agent and tool designed to provide up-to-date documentation for LLMs and AI code editors
    - LeanCTX - An open-source context compression tool that reduces AI coding assistant token usage by compressing file reads and shell output by up to 99%, working with 29+ AI tools like Cursor and Claude Code
- Semantic Code Retrieval
    - Serena - A powerful coding agent toolkit providing semantic retrieval and editing capabilities
- Session Tracking
    - Entire - A CLI tool that hooks into your git workflow to capture AI agent sessions on every push, creating a searchable record of how code was written and the intent behind every commit

08 - OS & Network Basics

Core OS Concepts

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Cloud Infrastructure Utilization

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- System call - The programmatic way in which a computer program requests a service from the kernel of the operating system on which it is executed
- Protection ring - A mechanism to protect data and functionality from faults and malicious behavior
- Daemon - A computer program that runs as a background process, rather than being under the direct control of an interactive user
- Environment variable - A named variable whose value is set outside the program, typically through functionality built into the operating system or a microservice
- POSIX standard - A family of standards specified by the IEEE Computer Society for maintaining compatibility between operating systems

Process Management

- Process - The instance of a computer program that is being executed by one or more threads
  - Thread - The smallest sequence of programmed instructions that can be managed independently by a scheduler
  - Scheduling - The action of assigning resources to perform tasks
  - Context switch - The process of storing the state of a process or thread, so that it can be restored and resume execution at a later point
  - Interrupt - A request for the processor to interrupt currently executing code, so that the event can be processed in a timely manner

Inter-Process Communication (IPC)

- Pipes
  - Anonymous pipe - A simplex FIFO communication channel that may be used for one-way interprocess communication
  - Named pipe - An extension to the traditional pipe concept on Unix and Unix-like systems, and is one of the methods of inter-process communication
- Shared memory - A memory that may be simultaneously accessed by multiple programs with an intent to provide communication among them or avoid redundant copies
- Signal - An asynchronous notification sent to a process or to a specific thread within the same process in order to notify it of an event that occurred
- Unix domain socket - A data communications endpoint for exchanging data between processes executing on the same host operating system

Memory Management

- Virtual memory - A memory management technique that provides an idealized abstraction of the storage resources that are actually available on a given machine
  - Memory paging - A memory management scheme by which a computer stores and retrieves data from secondary storage for use in main memory
  - Page fault - A type of exception raised by computer hardware when a running program accesses a memory page that is not currently mapped by the memory management unit into the virtual address space of a process
  - Resident set size (RSS) - The portion of memory occupied by a process that is held in main memory
  - Working set size (WSS) - The set of pages in the virtual address space of the process that are currently resident in main memory
- Page cache - A hardware or software component that stores data so that future requests for that data can be served faster

Storage Management

- Disk partitioning - The creation of one or more regions on a secondary storage device, so that each region can be managed separately
- Loop device - A pseudo-device that makes a file accessible as a block device
- File system - A method and data structure that the operating system uses to control how data is stored and retrieved
  - Journaling file system - A file system that keeps a journal, a circular log of changes that have not yet been committed to the main part of the file system
  - Path - The general form of the name of a file or directory, specifies a unique location in a file system
  - Glob pattern - A pattern that specifies sets of filenames with wildcard characters
  - File handle/descriptor - A unique identifier for a file or other input/output resource, such as a pipe or network socket
  - Symbolic link - A term for any file that contains a reference to another file or directory in the form of an absolute or relative path and that affects pathname resolution
  - Permissions - A feature of many modern file systems which control the ability of the users of a computer to view, change, navigate, and execute the contents of the file system
    - Setuid - A Unix access rights flag that allows users to run an executable with the permissions of the executable's owner or group
    - Sticky bit - A user ownership access right flag that can be assigned to files and directories on Unix-like systems
  - Inode - A data structure in a Unix-style file system that describes a file-system object such as a file or a directory

- RAID - A data storage virtualization technology that combines multiple physical disk drive components into one or more logical units for the purposes of data redundancy, performance improvement, or both

Base Network Concepts & Protocols

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Cloud Infrastructure Utilization

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- The OSI Model - A conceptual model that provides a common basis for the coordination of standards development for the purpose of systems interconnection

Link Layer (L2)

- Ethernet - A family of wired computer networking technologies
  - ARP - A communication protocol used for discovering the link layer address, such as a MAC address, associated with a given internet layer address
    - MAC address - A unique identifier assigned to a network interface controller for use as a network address in communications within a network segment
  - VLAN - A broadcast domain that is partitioned and isolated in a computer network at the data link layer

Internet Layer (L3)

- The Internet - The global system of interconnected computer networks that uses the Internet protocol suite to communicate between networks and devices
- IP - The network layer communications protocol in the Internet protocol suite
  - Link-local address - A network address that is valid only for communications within the network segment or the broadcast domain that the host is connected to
  - IP-multicast - A method of sending Internet Protocol datagrams to a group of interested receivers in a single transmission
  - IPv6 - The most recent version of the Internet Protocol, the communications protocol that provides an identification and location system for computers on networks and routes traffic across the Internet
    - Unique local address - An IPv6 address in the address block fc00::/7
  - ICMP - A supporting protocol in the Internet protocol suite
  - ICMPv6 - The implementation of the Internet Control Message Protocol for Internet Protocol version 6
  - DHCP - A network management protocol used on Internet Protocol networks for automatically assigning IP addresses and other communication parameters to devices connected to the network

  - DHCPv6 - A network protocol for configuring Internet Protocol version 6 hosts with IP addresses, IP prefixes and other configuration data required to operate in an IPv6 network
  - NAT - A method of mapping an IP address space into another by modifying network address information in the IP header of packets while they are in transit across a traffic routing device
  - NAT64 - An IPv6 transition mechanism that facilitates communication between IPv6 and IPv4 hosts
  - NDP - A protocol in the Internet protocol suite used with Internet Protocol Version 6
- Routing
  - Routing table - A data table stored in a router or a network host that lists the routes to particular network destinations
  - CIDR - A method for allocating IP addresses and for IP routing

Transport Layer (L4)

- Network socket - A software structure within a network node of a computer network that serves as an endpoint for sending and receiving data across the network
- TCP - A main protocol of the Internet protocol suite
  - TCP window scale option - An option to increase the receive window size allowed in Transmission Control Protocol above its former maximum value of 65,535 bytes
- UDP - A core member of the Internet protocol suite
- QUIC - A UDP-based, stream-multiplexing, encrypted transport protocol

Network Architectures

- Peer-to-peer - A distributed computing or networking architecture in which participants share resources directly without reliance on a centralized administrative system

Domain Name System (DNS)

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Cloud Infrastructure Utilization

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- DNS - The hierarchical and decentralized naming system used to identify computers, services, and other resources reachable through the Internet or other Internet Protocol networks
- mDNS - A protocol that resolves hostnames to IP addresses within small networks that do not include a local name server

Domain Registration & Lookup

- IANA WHOIS Service - A service to look up the registration data of a domain name or IP address
- Registration Data Access Protocol (RDAP) - A computer network communications protocol that delivers registration data from Domain Name Registries and Regional Internet Registries

Server & Resolver Implementations

- BIND (dnsutils) - A very flexible, full-featured DNS system
- dnsmasq - A lightweight, easy to configure DNS forwarder, DHCP and router advertisement server
- CoreDNS - A DNS server that chains plugins
- systemd-resolved - A system service that provides network name resolution to local applications
- mDNS Implementations
  - Avahi - A system which facilitates service discovery on a local network via the mDNS/DNS-SD protocol suite
  - Bonjour - Apple’s implementation of zero-configuration networking

Client Tools

- Part of BIND
  - dig - A flexible tool for interrogating DNS name servers
  - nslookup - A program to query Internet domain name servers
- dog - A command-line DNS client
- Doggo - A modern command-line DNS client (like dig) written in Go
- Managed DNS Services
  - Amazon Route53 - A highly available and scalable cloud Domain Name System web service
  - Google Cloud DNS - A high-performance, resilient, global Domain Name System service that publishes your domain names to the global DNS in a cost-effective way

Email System

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Cloud Infrastructure Utilization

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- Email - A method of exchanging messages between people using electronic devices

- SMTP - A communication protocol for electronic mail transmission
- POP - An application-layer Internet standard protocol used by e-mail clients to retrieve e-mail from a mail server
- IMAP - An Internet standard protocol used by email clients to retrieve email messages from a mail server over a TCP/IP connection
- MIME - A standard that extends the format of email messages to support text in character sets other than ASCII
  - Quoted-printable encoding - An encoding that represents data in the 8-bit ASCII character set, so that it can be sent using a 7-bit data path
  - Base64 - A group of binary-to-text encoding schemes that represent binary data in an ASCII string format by translating it into a radix-64 representation

Mailbox Formats

- Unix Mbox
- Maildir

Server Software (MTA/MDA)

- Postfix - A mail server that started life at IBM research as an alternative to the widely-used Sendmail program
- Maddy Mail Server - An all-in-one mail server that implements all functionality required to run a mail service
- IMAP
  - Cyrus IMAP - A highly scalable enterprise mail system designed for use in small to large enterprise environments
  - Dovecot - An open source IMAP and POP3 email server for Linux/UNIX-like systems

Client Software & Utilities

- TUI Clients & Utilities
  - mailutils - A set of libraries and utilities for handling electronic mail
    - mail command - A command to send and receive mail
  - Himalaya - A CLI application for email management, built in Rust, that allows users to interact with emails through shell commands, with support for IMAP, Maildir, SMTP, OAuth 2.0, and PGP encryption
  - Mutt - A small but very powerful text based program for reading and sending electronic mail under unix operating systems
  - swaks - A featureful, flexible, scriptable, transaction-oriented SMTP test tool
  - Pop - A library for sending emails from your terminal
  - GNU sharutils - A set of utilities for creating and unpacking shell archives

- Libraries
  - go-mail - A simple to use, yet feature rich mail library for Go
- GUI Clients
  - Thunderbird - A free email application that's easy to set up and customize
  - Sylpheed - A simple, lightweight but featureful, and easy-to-use e-mail client

Spam Test and Reputation

- mail-tester - A free online service that allows you to test your emails for Spam, Malformed Content and Mail Server Configuration problems
- Spamhaus Project - A non-profit organization that tracks spam and related cyber threats
- Cloud Services
  - Amazon SES - A cost-effective, flexible, and scalable email service that enables developers to send mail from within any application
  - SendGrid - A cloud-based email delivery platform that provides reliable transactional and marketing email delivery at scale

Unix-like Operating Systems

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Cloud Infrastructure Utilization

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- The Linux Kernel - The main component of a Linux operating system and is the core interface between a computer's hardware and its processes
  - Threads
    - Pthreads - An execution model that exists independently from a programming language, as well as a parallel execution model
  - Filesystems
    - Ext4 - The default file system for many major Linux distributions
    - XFS - A high-performance journaling file system created by Silicon Graphics, Inc
    - Btrfs - A copy-on-write filesystem for Linux with advanced features including snapshots, RAID, and self-healing
    - UnionFS - A filesystem service for Linux, FreeBSD and NetBSD which implements a union mount for other file systems
    - OverlayFS - A union mount filesystem implementation for Linux
    - proc.5 - A virtual filesystem that provides an interface to kernel data structures
    - sysfs.5 - A virtual filesystem that exports information about various kernel subsystems, hardware devices, and associated device drivers

    - Container Support
        - cgroups - A Linux kernel feature which allow processes to be organized into hierarchical groups whose usage of various types of resources can then be limited and monitored
        - namespaces - A wrapper for a global system resource in an abstraction that makes it appear to the processes within the namespace that they have their own isolated instance of the global resource
        - lxc/rootfs - The userspace interface for the Linux kernel containment features
        - nsenter - A command that executes a program in the namespaces of other processes
    - FUSE (Filesystem in Userspace) - An interface for userspace programs to export a filesystem to the Linux kernel
        - s3fs - A FUSE filesystem that allows you to mount an Amazon S3 bucket as a local filesystem
    - eBPF (Extended Berkeley Packet Filter) - A revolutionary technology with origins in the Linux kernel that can run sandboxed programs in a privileged context

Linux Distributions

- General Purpose
    - Arch Linux - A simple, lightweight distribution
    - Debian - A complete Free Operating System
    - Fedora - An innovative, free and open-source operating system platform built by the community for hardware, clouds, and containers
    - Gentoo - A highly flexible, source-based Linux distribution that emphasizes customization and performance
    - NixOS - A Linux distribution with a unique approach to package and configuration management
    - openSUSE - A free Linux operating system for desktops, servers and containers
- Server-focused
    - Ubuntu server - The standard platform for public clouds, on-premises, and IoT devices
- Desktop-focused
    - Debian-based
        - Ubuntu desktop - The Linux-based operating system that runs from the desktop, to the cloud, to all your internet connected things
        - BunsenLabs Linux - A distribution offering a light-weight and easily customizable Openbox desktop
    - Arch-based

    - Manjaro Linux - A user-friendly Linux distribution based on the independently developed Arch operating system
    - Mabox Linux - Fast, lightweight and functional Linux Desktop "relaxed" rolling-release, Manjaro based with Openbox Window Manager

BSD Distributions

- FreeBSD - A free and open-source Unix-like operating system descended from the Berkeley Software Distribution (BSD)
- NetBSD - A free, fast, secure, and highly portable Unix-like Open Source operating system
- OpenBSD - A free and open-source, Unix-like operating system as a fork of NetBSD that emphasizes extremely high security and cryptography

System Services & Auth

- Systemd - A system and service manager for Linux operating systems
    - journald - A system service that collects and stores logging data
    - hostnamed - A system service that may be used to control the hostname and related machine metadata from user programs
    - networkd - A system service that manages networks
    - resolved - A system service that provides network name resolution to local applications
    - timesyncd - A system service that may be used to synchronize the local system clock with a remote Network Time Protocol server
- linux-pam - A system of libraries that handle the authentication tasks of applications and services in a Linux system

Machine Virtualization

:::note[Relevant DSS-P Skills]

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- Virtualization - The act of creating a virtual version of something, including virtual computer hardware platforms, storage devices, and computer network resources
- libvirt - A toolkit to manage virtualization platforms

Type-1 Hypervisors

- KVM - A full virtualization solution for Linux on x86 hardware containing virtualization extensions

- Hyper-V - A hardware virtualization product from Microsoft
- Proxmox VE - A complete, open-source server management platform for enterprise virtualization

Type-2 Hypervisors

- VirtualBox - A powerful x86 and AMD64/Intel64 virtualization product for enterprise as well as home use
- QEMU - A generic and open source machine emulator and virtualizer

CPU Emulators

- QEMU - A generic and open source machine emulator and virtualizer

Computer Hardware

- CPU Architectures
  - x86-64 - A 64-bit version of the x86 instruction set
  - ARM64 - The 64-bit extension of the ARM architecture family
- CPU Extensions
  - x86 virtualization
  - Intel AMX

Linux Host Administration

:::note[Relevant DSS-P Skills]

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  ==== Core Utilities

- util-linux - A random collection of Linux utilities
  - lsblk - A command that lists information about all available or the specified block devices
  - lsns - A command that lists information about all the currently accessible namespaces or about the given namespace
  - swapon - A command used to specify devices on which paging and swapping are to take place
- rsync - An open source utility that provides fast incremental file transfer
- sudo - A system administrator to delegate authority to give certain users the ability to run some commands as root or another user

- shadow-utils - includes the necessary programs for converting UNIX password files to the shadow password format, plus programs for managing user and group accounts
  - useradd - A low level utility for adding users
- jc - A CLI tool and Python library that converts the output of popular command-line tools and file-types to JSON or Dictionaries
- aha - An Ansi HTML Adapter
  - NO_COLOR - An environment variable to disable ANSI color in command-line software
- Vixie Cron - An open source implementation of POSIX Cron
  - Crontab.guru - A quick and simple editor for cron schedule expressions
- logrotate - allows for the automatic rotation compression, removal and mailing of log files
- Syslog - A standard for message logging

Process & System Monitoring

- procps - A set of command line and full-screen utilities that provide information out of the pseudo-filesystem most commonly located at /proc
  - ps - A command that displays information about a selection of the active processes
  - top - A program that provides a dynamic real-time view of a running system
  - free - A command that displays the total amount of free and used physical and swap memory in the system
  - vmstat - A command that reports information about processes, memory, paging, block IO, traps, disks and cpu activity
- psmisc - A package of small utilities that use the proc file-system
  - pstree - A command that shows running processes as a tree
  - killall - A command that sends a signal to all processes running any of the specified commands
- lsof - A command for LiSting Open Files
- strace - A diagnostic, debugging and instructional userspace utility for Linux
- inxi - A full featured system information script
- witr - A tool that explains the causal ancestry and purpose of running processes
- Performance Monitors
  - sysstat - A collection of performance monitoring tools for Linux
    - iostat - A command used for monitoring system input/output device loading
  - Monit - A small Open Source utility for managing and monitoring Unix systems
  - atop - An ASCII full-screen performance monitor for Linux
  - smem - A tool that can give numerous reports on memory usage on Linux systems

Time Synchronization

- NTP - A networking protocol for clock synchronization between computer systems over packet-switched, variable-latency data networks
- chrony - A versatile implementation of the Network Time Protocol
- pool.ntp.org - A big virtual cluster of timeservers providing reliable easy to use NTP service for millions of clients

Modern CLI Alternatives

- gdu - A fast disk usage analyzer with a console interface written in Go
- lsd - A rewrite of GNU ls with a lot of added features like colors, icons, tree-view, and more formatting options
- eza - A modern replacement for ls
- broot - A new way to see and navigate directory trees
- bat - A cat(1) clone with wings
- dust - A more intuitive version of du in rust
- dua - A tool to view disk space usage and delete unwanted data, fast
- duf - A better 'df' alternative
- procs - A modern replacement for ps written in Rust
- htop - An interactive process viewer for Unix systems
- btop++ - A resource monitor for Linux, macOS, and FreeBSD
- glances - A cross-platform monitoring tool which aims to present a large amount of monitoring information through a curses or Web based interface
- neofetch - A command-line system information tool

Package Management Tools

- dpkg - The base package management system for Debian
  - apt - A command-line utility for installing, updating, removing, and otherwise managing deb packages on Ubuntu, Debian, and related Linux distributions
- Pacman - A utility which manages software packages in Linux
  - Yay - An AUR Helper Written in Go
- yum - An automatic updater and package installer/remover for rpm systems
- dnf - The next-generation version of yum
- Homebrew - The Missing Package Manager for macOS (or Linux)
- pipx - A tool to install and run Python applications in isolated environments
- Flatpak - A system for building, distributing, and running sandboxed desktop applications on Linux

- Snapcraft - A software packaging and deployment system developed by Canonical for operating systems that use the Linux kernel
- arkade - A portable marketplace for downloading your favourite devops CLIs and installing helm charts to your Kubernetes cluster

Linux Network Administration

:::note[Relevant DSS-P Skills]

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  ==== Configuration & Management

- iproute2 - A collection of utilities for controlling TCP / IP networking and traffic control in Linux
  - ip - The main command to show / manipulate routing, network devices, interfaces and tunnels
  - ss - A utility to investigate sockets
- net-tools (legacy) - A collection of programs for controlling the network subsystem of the Linux kernel
  - ifconfig - A command used to configure a network interface
  - netstat - A command that prints network connections, routing tables, interface statistics, masquerade connections, and multicast memberships
- NetworkManager - A daemon that sits on top of libudev and other Linux kernel interfaces and provides a high-level interface for network configuration
- Ubuntu NetPlan - A network configuration abstraction renderer

Analysis & Security

- tcpdump - A powerful command-line packet analyzer
- wireshark - The world's foremost network protocol analyzer
- nmap - An open source tool for network exploration and security auditing
  - ncat - A feature-packed networking utility which reads and writes data across networks from the command line
- traceroute - A computer network diagnostic tool for displaying the route and measuring transit delays of packets across an Internet Protocol network

Proxies & Gateways

- SOCKS Proxy - An Internet protocol that exchanges network packets between a client and server through a proxy server
  - Dante - A SOCKS server and SOCKS client, implementing RFC 1928 and related

standards

- tun2socks - A SOCKS proxy for TCP and UDP, that handles all connections from a TUN device
- proxychains - A tool that forces any TCP connection made by any given application to follow through proxy like TOR or any other SOCKS4, SOCKS5 or HTTP(S) proxy

File Sharing & Remote Access

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Cloud Infrastructure Utilization

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  ==== File Servers and Protocols

- SMB - A network communication protocol for providing shared access to files, printers, and serial ports between nodes on a network
  - Samba - The standard Windows interoperability suite of programs for Linux and Unix
- FTP - A standard communication protocol used for the transfer of computer files from a server to a client on a computer network
  - vsftpd - A GPL licensed FTP server for UNIX-like systems, including Linux
- SFTP - A network protocol that provides file access, file transfer, and file management over any reliable data stream
  - SFTPGo - A fully featured and highly configurable SFTP server with optional HTTP/S, FTP/S and WebDAV support

Remote Access Servers and Protocols

- SSH - A cryptographic network protocol for operating network services securely over an unsecured network
  - openssh - The premier connectivity tool for remote login with the SSH protocol
- RDP - A proprietary protocol developed by Microsoft which provides a user with a graphical interface to connect to another computer over a network connection
  - xrdp - An open-source Remote Desktop Protocol server
- RFB - A simple protocol for remote access to graphical user interfaces
  - x11vnc - A VNC server for X11
  - TightVNC - A free remote desktop application
- Mosh - A replacement for interactive SSH terminals

09 - Programming Concepts & Paradigms

Software Design & Architecture

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Software Design Methodology

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  ==== Design Principles

- Orthogonality and DRY principle - The principle that every piece of knowledge must have a single, unambiguous, authoritative representation within a system
- Separation of concerns - A design principle for separating a computer program into distinct sections
- Design by Contract - An approach for designing software that prescribes formal, precise and verifiable interface specifications for software components
- Law of Demeter - A design guideline for developing software, particularly object-oriented programs
- SOLID - The principle of OOD - A mnemonic acronym for five design principles intended to make object-oriented designs more understandable, flexible, and maintainable
  - Single responsibility
  - Open–closed
  - Liskov substitution
  - Interface segregation
  - Dependency inversion
- The Reactive Manifesto - A coherent approach to systems architecture where applications are responsive, resilient, elastic and message driven
- Unix philosophy - A set of cultural norms and philosophical approaches to software development
- KISS principle - A design principle which states that most systems work best if they are kept simple rather than made complicated

Design Best Practices

- Resource acquisition is initialization (RAII) - A programming idiom where the life cycle of a resource is bound to the lifetime of an object
- Rob Pike's 5 Rules of Programming - A set of rules about where to focus optimization efforts, emphasizing measurement and the importance of data structures
- The Zen of Python - A collection of 19 guiding principles for writing computer programs that influence the design of the Python programming language
- The twelve-factor app - A methodology for building software-as-a-service apps that are suitable for deployment on modern cloud platforms

Design Patterns

- Software design pattern - A general, reusable solution to a commonly occurring problem within a given context in software design
- Entity–control–boundary - An architectural pattern used in software design and analysis that helps in structuring the responsibilities of classes in an object-oriented system
- Command Query Responsibility Segregation - A pattern that separates read and update operations for a data store
- Fluent interface - A method for designing object-oriented APIs based on method chaining with the goal of making the readability of the source code close to that of ordinary written prose
- Model-view-controller pattern - A software design pattern commonly used for developing user interfaces that divides the related program logic into three interconnected elements
- Dependency injection - A design pattern in which an object or function receives other objects or functions that it depends on

Architectural Styles

- Three-tier architecture - A client–server architecture in which presentation, application processing, and data management functions are logically separated
- Microservices architecture - An approach to developing a single application as a suite of small services, each running in its own process and communicating with lightweight mechanisms
- Event-driven architecture - A software architecture paradigm promoting the production, detection, consumption of, and reaction to events
- Resource-oriented architecture - A style of software architecture and programming paradigm for designing and developing software in the form of a network of resources
- Background processing - The execution of tasks in the background, allowing the main application to remain responsive

Architecture Description

- System - A group of interacting or interrelated elements that act according to a set of rules to form a unified whole
  - Systems architecture - The conceptual model that defines the structure, behavior, and more views of a system
    - 4+1 architectural view model - A view model used for "describing the architecture of software-intensive systems, based on the use of multiple, concurrent views"
    - The C4 model - An easy to learn, developer friendly approach to software architecture diagramming
    - UML - The graphical language for visualizing, specifying, constructing, and documenting the artifacts of a software-intensive system

        - Flowchart - A type of diagram that represents a workflow or process
    - Conway's law - An adage stating that organizations design systems that mirror their own communication structure
- Related Standards
    - ISO/IEC/IEEE 42010 (Architecture description) - An international standard for architecture descriptions of systems and software

Domain-Driven Design (DDD)

- Domain-driven design - A major software design approach, focusing on modeling software to match a domain according to input from that domain's experts
- Object-oriented analysis and design - A technical approach for analyzing and designing an application, system, or business by applying object-oriented programming, as well as using visual modeling throughout the software development process
    - Use case - A list of actions or event steps typically defining the interactions between a role (known in the Unified Modeling Language as an actor) and a system to achieve a goal
- Ontology - A representation, formal naming and definition of the categories, properties and relations between the concepts, data and entities that substantiate one, many or all domains of discourse
    - Semantic network - A knowledge base that represents semantic relations between concepts in a network
        - WordNet - A large lexical database of English
- Database design - The organization of data according to a database model

Core Programming Concepts

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Computer Science

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  ==== Language Mechanics & Execution

- Source code - A collection of code, possibly with comments, written using a human-readable programming language, usually as plain text
- Statement - A syntactic unit of an imperative programming language that expresses some action to be carried out
- Expression - A syntactic entity in a programming language that may be evaluated to determine its value
    - Operator and Operand
- Literal - A notation for representing a fixed value in source code

  - Template string or literal
  - Heredoc - A file literal or input stream literal representing a section of source code that is treated as if it were a separate file
- Constant - A value that cannot be altered by the program during normal execution
- Variable - An abstract storage location paired with an associated symbolic name, which contains some known or unknown quantity of information referred to as a value
- Scope - The region of a computer program where the binding of a name to an entity (name binding) is valid
- Data type - A collection or grouping of data values, usually specified by a set of possible values and allowed operations
  - Primitives - A data type provided by a programming language as a basic building block or one not defined in terms of other data types
  - Nominal type system - A major class of type systems, in which compatibility and equivalence of data types is determined by explicit declarations and/or the names of the types
  - Structural type system - A major class of type systems in which type compatibility and equivalence are determined by the type's actual structure or definition
  - Duck typing - An application of the duck test determining type compatibility based on the presence of certain methods and properties
  - Union type - A data type definition that specifies which of a number of permitted primitive types may be stored in its instances
  - Type variance - The relationship between subtypes of a composite type and the subtypes of its components
  - Type safety - The extent to which a programming language discourages or prevents type errors
- Reference - A value that enables a program to indirectly access a particular datum in the computer's memory or other storage device
  - Null pointer - A value saved for indicating that the pointer or reference does not refer to a valid object

Memory Management

- Reference counting - A programming technique of storing the number of references, pointers, or handles to a resource
- Garbage collection - A form of automatic memory management where the collector attempts to reclaim memory occupied by objects no longer in use
- Smart pointer - An abstract data type that simulates a pointer while providing added features, such as automatic memory management or bounds checking
- Memory safety - The state of being protected from various software bugs and security vulnerabilities when dealing with memory access

Control Flow Structures

- Control flow - The order in which individual statements, instructions or function calls of an imperative program are executed or evaluated
- Continuation - A data structure that represents the rest of a program's computation at a given point
  - call-with-current-continuation - A control flow operator, notably in the Scheme programming language, used to capture and invoke continuations
- Exception handling - The process of responding to the occurrence of exceptions during the execution of a program
- Finite-state machine - A mathematical model of computation representing an abstract machine that can be in exactly one of a finite number of states at any given time

Foundational Techniques & Properties

- State - The stored information, at a given instant in time, to which a computer program or system has access
- Function - A sequence of program instructions that performs a specific task, packaged as a unit
  - Parameter - A special kind of variable used in a subroutine or function to refer to one of the pieces of data provided as input
  - Anonymous function - A function definition that is not bound to an identifier
- Immutable object - An object whose state cannot be modified after it is created
- Generic Programming - A style of computer programming in which algorithms are written in terms of types to-be-specified-later that are then instantiated when needed
- Assertion - A statement that a predicate (a Boolean-valued function) is expected to always be true at that point in the code
- Autovivification - The automatic creation of a new variable or data structure as required when it is first used

Module Structure & Organization

- Cohesion - The degree to which the elements inside a module belong together
- Coupling - The degree of interdependence between software modules, a measure of how closely connected two routines or modules are, and the strength of the relationships between modules

Programming Paradigms

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Computer Science

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==== Object-oriented Programming

- Object-oriented Programming - A programming paradigm based on the object - a software entity that encapsulates data and function(s)
  - Abstraction - The process of hiding the complexity of a system by modeling classes appropriate to the problem and working at the most relevant level of detail
  - Encapsulation - The bundling of data with the methods that operate on that data, or the restricting of direct access to some of an object's components
  - Polymorphism - The provision of a single interface to entities of different types
    - Dynamic dispatch - The process of selecting which implementation of a polymorphic operation (method or function) to call at run time
  - Inheritance - The mechanism of basing an object or class upon another object or class, retaining similar implementation
  - Class - An extensible program-code-template for creating objects, providing initial values for state and implementations of behavior
  - Interface - An abstract type that contains no data, but defines behaviors as method signatures
  - Method - A procedure associated with an object, and implicitly acting upon that object
  - This keyword - A keyword used in many object-oriented programming languages to refer to the object associated with the current function or method call
  - Prototype-based programming - A style of object-oriented programming in which behavior reuse is performed via a process of reusing existing objects that serve as prototypes

Functional Programming

- Functional Programming - A programming paradigm where programs are constructed by applying and composing functions
  - Algebraic data type - A composite data type formed by combining other types
  - Pattern matching - The act of checking a given sequence of tokens for the presence of the constituents of some pattern
  - First-class function - The property of a programming language that treats functions as first-class citizens (e.g., assignable to variables, passable as arguments)
    - Map - A higher-order function that applies a given function to each element of a sequence, returning a sequence containing the results
    - Filter - A higher-order function that processes a data structure to produce a new data structure containing only those elements for which a given predicate returns true
    - Reduce - A higher-order function (also known as fold) that reduces a data structure to a single value by recursively applying a combining operation

    - Referential transparency - A property of expressions such that an expression can be replaced with its corresponding value without changing the program's behavior
    - Closure - A function together with a referencing environment for the non-local variables of that function
    - Side-effect - An observable effect of an operation, function, or expression that modifies state variable values outside its local environment
    - Monad - A software design pattern with a structure that combines program fragments (functions) and wraps their return values in a type with additional computation
    - Currying - The technique of converting a function that takes multiple arguments into a sequence of functions that each takes a single argument

Reactive Programming & Others

- Reactive Programming - A declarative programming paradigm concerned with data streams and the propagation of change
    - Functional Reactive Programming (FRP) - A programming paradigm for reactive programming using the building blocks of functional programming
    - Languages & Frameworks
        · RO - A library for streams and reactive programming for Go
        · ReactiveX - An API for asynchronous programming with observable streams
        · Elm - A delightful language for reliable web applications
- Aspect-oriented Programming - A programming paradigm that aims to increase modularity by allowing the separation of cross-cutting concerns
    - Cross-cutting concern - An aspect of a program that affect several modules, without the possibility of being encapsulated in any of them

Scripting Languages

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Computer Science

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  ==== Python

- Python - A programming language that lets you work quickly and integrate systems more effectively
    - Core Features
        · Python import system - The mechanism that organizes Python code into modules and packages, facilitating code reuse and structuring large applications
        · Special method names - The methods, identified by leading and trailing double underscores, that allow classes to implement operations invoked by special

syntax

  - Type Hints - A standard syntax for type annotations of variables, function parameters, and return values, used for static analysis
    - typing module - The standard library module providing runtime support for type hints
    - Mypy - An optional static type checker for Python that aims to combine the benefits of dynamic typing and static typing
  - f-string - A type of string literal, prefixed with 'f' or 'F', which allows embedding expressions inside string constants using minimal syntax
  - with statement - A statement that simplifies exception handling by encapsulating standard uses of try/finally statements for resource management
    - contextlib - A module that provides utilities for common tasks involving the with statement
  - Generators - A simple and powerful way to create iterators, defined using a function with the yield statement
  - Decorators - A syntax using the '@' symbol for transforming functions and methods, often used for modifying or enhancing them non-intrusively
  - Coroutine - A specialized generator function, defined with `async def`, that can suspend and resume its execution, enabling cooperative multitasking
  - Lambda - A small anonymous function defined using the `lambda` keyword, restricted to a single expression
  - Data Classes - A module and decorator providing a concise way to create classes primarily used to store data, automatically generating special methods
  - Pattern Matching - A feature providing functionality similar to switch statements, allowing matching of values against complex patterns including sequences, mappings, and object structures
  - Unpacking Operator - The extended usages of the `iterable unpacking operator` and `*` dictionary unpacking operators to allow unpacking in more positions, an arbitrary number of times, and in additional circumstances

- Key Libraries
  - pathlib - The module offering classes representing filesystem paths with semantics appropriate for different operating systems
  - dotenv - A library that reads key-value pairs from a .env file and can set them as environment variables
  - Pydantic - A data validation and settings management library for Python
  - Tenacity - A general-purpose retrying library for Python
- Development Tools
  - IPython - A rich interactive interface to Python with a history mechanism, tab completion, and special magic commands

JavaScript & TypeScript

- JavaScript/ECMAScript - The standard that defines the ECMAScript Language
  - Module System
    - CommonJS - A project with the goal of specifying an ecosystem for JavaScript outside the browser
    - ES modules - The official standard format to package JavaScript code for reuse
    - UMD - The patterns for Universal Module Definition for use in the browser, and in AMD and CommonJS-based systems
  - Core Features
    - Event-driven - A programming paradigm in which the flow of the program is determined by events such as user actions, sensor outputs, or messages from other programs
    - Spread and rest operators - The syntax that allows an iterable such as an array expression or string to be expanded in places where zero or more arguments or elements are expected
    - Generator - An object returned by a generator function and it conforms to both the iterable protocol and the iterator protocol
  - Key Libraries
    - Lodash - A modern JavaScript utility library delivering modularity, performance & extras
    - dax - Cross-platform shell tools for Deno and Node.js inspired by zx
    - Bun Shell - A built-in shell-like interface for running shell scripts
    - zx - A tool for writing better scripts
    - Zod - A TypeScript-first schema validation with static type inference
    - yup - A schema builder for runtime value parsing and validation
  - Typescript - A strongly typed programming language that builds on JavaScript, giving you better tooling at any scale
    - Union Types - A way to combine multiple types into one
    - Type Aliases - A name for any type
    - Type Assertions - A way to tell the compiler 'trust me, I know what I'm doing'
    - Mapped Types - A generic type which uses a union of PropertyKeys to iterate through keys of another type to create a new one
    - Nominal typing techniques - A way to simulate nominal types in TypeScript, which by default has a structural type system
    - Declaration Files - The files where you define the types for a library
    - Decorators - A special kind of declaration that can be attached to a class declaration, method, accessor, property, or parameter

    - TS Type Utilities
        - json-schema-to-typescript - A tool to compile JSONSchema to TypeScript type declarations
        - Json Schema to TS - The FromSchema method lets you infer TS types directly from JSON schemas
- Tutorials & Practices
    - 33 JS Concepts - A repository with articles about 33 concepts every JavaScript developer should know
    - JS Project Guidelines - A set of best practices for JavaScript projects
    - Callback Hell - The nesting of callback functions when dealing with asynchronous logic
    - NodeSchool - A set of open source workshops that teach web software skills
    - Node.js Best Practices - A summary and curation of the top-ranked content on Node.js best practices

Ruby, Perl & Others

- Ruby - A dynamic, open source programming language with a focus on simplicity and productivity
    - Core Features
        - Percent notation - A concise syntax for generating various literal types, such as strings, arrays, and regular expressions, using a percent sign and delimiters
        - Fiber - A lightweight concurrency primitive that allows for cooperative multitasking by pausing and resuming execution
        - proc - A mechanism to encapsulate a block of code into an object that can be stored, passed, and executed
        - lambda - A specialized block object that enforces strict argument checking and localized return behavior
        - then - A method that yields the object itself to a block and returns the result, facilitating functional-style method chaining
        - define_method - The ability to create and register methods at runtime using `define_method`, enhancing code flexibility and reducing repetition
        - instance_eval - A method that evaluates a block or string within the context of a specific object instance, granting access to its internal scope and private methods
    - Libraries
        - io-event - The low level cross-platform primitives for constructing event loops
        - Async - A composable asynchronous I/O framework for Ruby based on io-event
    - Development Tools
        - IRB (Interactive Ruby) - A tool to interactively execute Ruby expressions read

from the standard input

- Perl - A family of two high-level, general-purpose, interpreted, dynamic programming languages
  - Core Features
    - Special variables - The variables that have a special meaning to Perl
    - Built-in regex - The syntax of regular expressions in Perl
    - Context - A property of expressions that determines how they behave when evaluated
    - Scalar values - A single item of data
      - Reference - A scalar data type that 'points' to another piece of data
    - Quote-like operators - A set of generic quoting operators
    - I/O operators - The operators used for input and output operations, such as reading from a filehandle
- Tcl - A dynamic programming language and a graphical user interface toolkit used for a wide range of applications
  - Event-driven by design - The built-in event loop that makes it ideal for GUIs and networking
- Lua - A powerful, efficient, lightweight, embeddable scripting language
- Emacs Lisp - The programming language used to extend and customize the Emacs text editor
  - S-expression - A notation for nested list (tree-structured) data
  - Homoiconicity - A property of some programming languages in which the primary representation of programs is also a data structure in a primitive type of the language itself

Asynchronous & Concurrency

:::note[Relevant DSS-P Skills]

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- Concurrent computing - A form of computing in which several computations are executed concurrently instead of sequentially
  - Coroutine - A computer program component that generalizes subroutines for non-preemptive multitasking, by allowing execution to be suspended and resumed
  - Async/await - A syntactic feature that allows an asynchronous, non-blocking function to be structured in a way similar to an ordinary synchronous function
  - Futures and promises - The constructs used for synchronizing program execution, representing a proxy for a result that is initially unknown

  - Semaphore - A variable or abstract data type used to control access to a common resource by multiple threads in a concurrent system
  - Mutex - A synchronization primitive that prevents state from being modified or accessed by multiple threads of execution at the same time
  - Channel - A model for interprocess communication and synchronization via message passing
  - Thread safety - A property of computer code applicable in multi-threaded environments, ensuring correct manipulation of shared data structures
  - Deadlock - A situation in concurrent computing where no member of a group of entities can proceed because each waits for another member to take action

Language Analysis

:::note[Relevant DSS-P Skills]

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- Concepts
  - Formal language - A set of words, i.e. finite strings of letters, symbols, or tokens
    - Well-formed formula - A finite sequence of symbols from a given alphabet that is part of a formal language
  - Formal grammar - A set of formation rules for strings in a formal language
  - Chomsky hierarchy - A containment hierarchy of classes of formal grammars
  - Automata theory - The study of abstract machines and automata, as well as the computational problems that can be solved using them
  - Lexical Analysis (Tokenizing)
  - Syntactic Analysis (Parsing)
  - BNF syntax - A notation technique for context-free grammars, often used to describe the syntax of languages used in computing
  - AST - A tree representation of the abstract syntactic structure of source code written in a programming language
- Parser Generators
  - ANTLR - A powerful parser generator for reading, processing, executing, or translating structured text or binary files
  - Bison - A general-purpose parser generator that converts a grammar description for a context-free grammar into a C program to parse that grammar
- Lexer Generators
  - Flex - The Fast Lexical Analyzer - scanner generator
  - Ragel - A state machine compiler

- Parsers/Libraries
  - tree-sitter - A parser generator tool and an incremental parsing library
  - ts-morph - A TypeScript Compiler API wrapper

Program Translation

:::note[Relevant DSS-P Skills]

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- Concepts
  - Compiler - A computer program that translates computer code written in one programming language into another language
  - Transpiler - A type of translator that takes the source code of a program written in a programming language as its input and produces an equivalent source code in the same or a different programming language
    - Intermediate representation - The data structure or code used internally by a compiler or virtual machine to represent source code
  - Program optimization - The process of modifying a software system to make some aspect of it work more efficiently or use fewer resources
  - Machine code - A computer program written in machine language instructions that can be executed directly by a computer's central processing unit (CPU)
  - Cross compiler - A compiler capable of creating executable code for a platform other than the one on which the compiler is running
  - Linker - A computer system program that takes one or more object files and combines them into a single executable file

Major Compiler Infrastructures

- LLVM Compiler Infrastructure - A collection of modular and reusable compiler and toolchain technologies
  - Clang - A C language family frontend for LLVM
  - LLD - The LLVM Linker
- gcc - The GNU Compiler Collection which includes front ends for C, C++, Objective-C, Fortran, Ada, Go, and D
- rustc - The compiler for the Rust programming language

Specific Translators & Build Tools

- MinGW-w64 - An advancement of the original mingw.org project, created to support the GCC compiler on Windows systems

- Go build command - A tool for managing Go source code
  - Static binary executable
- GopherJS - A compiler from Go to JavaScript
- Bunster - A shell compiler that turns your scripts into a self-contained executable programs

Linkers (Standalone)

- mold - A Modern Linker
- Runtime Libraries
  - glibc - The GNU C Library project which provides the core libraries for the GNU system and GNU/Linux systems
  - musl libc - A C standard library intended for operating systems based on the Linux kernel

Program Execution

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Computer Science

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- Concepts
  - Runtime System - The part of a program that runs on a computer, for the language in which the program was written
  - Bytecode - A form of instruction set designed for efficient execution by a software interpreter
  - Just-in-time compilation - A way of executing computer code that involves compilation during execution of a program
  - Global interpreter lock - A mutex that protects access to Python objects, preventing multiple threads from executing Python bytecodes at the same time

Runtime Implementations

- Javascript
  - Node.js - A free, open-source, cross-platform JavaScript runtime environment
    - libuv - A multi-platform support library with a focus on asynchronous I/O
  - Deno - A modern runtime for TypeScript and JavaScript
    - Deno Deploy - A distributed HTTP service that allows you to run JavaScript, TypeScript, and WebAssembly at the edge
    - Deno Subhosting - A platform for SaaS providers to securely run untrusted customer code at scale using V8 isolates

  - Bun - A fast, all-in-one toolkit for running, building, testing, and debugging JavaScript and TypeScript
  - WinterJS - A blazingly fast JavaScript runtime built on Rust, using the SpiderMonkey engine and the Tokio runtime
- Python
  - CPython (default)
  - pypy - A fast, compliant alternative implementation of Python
  - Pyodide - A Python distribution for the browser and Node.js based on WebAssembly
- Ruby
  - CRuby (default)
  - JRuby - An implementation of the Ruby programming language atop the Java Virtual Machine
- Java SE - The most proven, trusted, and secure development platform for modern application development
  - Java HotSpot VM - The primary Java Virtual Machine for desktops and servers, produced by Oracle Corporation
  - JMX API - The Java Management Extensions technology which is a standard part of the Java Platform
  - JDK tools - The command-line tools to create and build applications
  - GraalVM - An advanced JDK with ahead-of-time Native Image compilation
  - OpenJDK - The place to collaborate on an open-source implementation of the Java Platform, Standard Edition
  - Eclipse Temurin - The open-source, enterprise-ready, and TCK-certified builds of OpenJDK
- .NET - The free, open-source, cross-platform framework for building modern apps and powerful cloud services
  - CLR - The virtual machine component of .NET Framework
- Runtime Utilities
  - PM2 - A daemon process manager that will help you manage and keep your application online
  - PyCall - A Ruby library that allows you to call Python functions from Ruby
  - VisualVM - An All-in-One Java Troubleshooting Tool

Algorithm & Computational Complexity

:::note[Relevant DSS-P Skills]

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- Concepts
  - Complexity class - A set of computational problems of related resource-based complexity
- Reference Resources
  - NIST Dictionary of Algorithms and Data Structures - A dictionary of algorithms, algorithmic techniques, data structures, archetypal problems, and related definitions

Algorithm

- Algorithm - A finite sequence of rigorous instructions, typically used to solve a class of specific problems or to perform a computation
  - Analysis Techniques
    - Amortized analysis - A method for analyzing a given algorithm’s complexity
    - Big O notation - A mathematical notation that describes the limiting behavior of a function when the argument tends towards a particular value or infinity
  - Algorithmic Paradigms
    - Recursion - A method of solving a computational problem where the solution depends on solutions to smaller instances of the same problem
    - Divide and conquer - An algorithm design paradigm
    - Dynamic programming - A method for solving a complex problem by breaking it down into a collection of simpler subproblems
    - Backtracking - A class of algorithms for finding solutions to some computational problems
    - Greedy algorithm - An algorithmic paradigm that follows the problem-solving heuristic of making the locally optimal choice at each stage
  - Sorting Algorithms
    - Quicksort - An in-place sorting algorithm
    - Merge sort - An efficient, general-purpose, and comparison-based sorting algorithm
    - Heapsort - A comparison-based sorting algorithm
  - Searching Algorithms
    - Binary search - A search algorithm that finds the position of a target value within a sorted array
    - Interpolation search - An algorithm for searching for a key in a sorted array that has been ordered by numerical values assigned to the keys
  - String Algorithms
    - Knuth–Morris–Pratt algorithm - A string-searching algorithm that searches for occurrences of a "word" W within a main text string T
    - Boyer–Moore algorithm - A string-searching algorithm that is the standard

benchmark for practical string-search literature

        - Longest common subsequence - The problem of finding the longest subsequence common to all sequences in a set of sequences
    - Graph Algorithms
        - Traversal
            - Breadth-first search - An algorithm for traversing or searching tree or graph data structures
            - Depth-first search - An algorithm for traversing or searching tree or graph data structures
        - Shortest Path
            - Dijkstra's algorithm - An algorithm for finding the shortest paths between nodes in a weighted graph
            - Bellman–Ford algorithm - An algorithm that computes shortest paths from a single source vertex to all of the other vertices in a weighted digraph
        - Minimum Spanning Tree - A subset of the edges of a connected, edge-weighted undirected graph that connects all the vertices together
            - Prim's algorithm - A greedy algorithm that finds a minimum spanning tree for a weighted undirected graph
            - Kruskal's algorithm - A minimum-spanning-tree algorithm which finds an edge of the least possible weight that connects any two trees in the forest
        - Other
            - Tarjan's strongly connected components algorithm - An algorithm in graph theory for finding the strongly connected components (SCCs) of a directed graph
            - Topological sorting - A linear ordering of the vertices of a directed acyclic graph (DAG)
    - Hashing Algorithms
        - Hash function - Any function that can be used to map data of arbitrary size to fixed-size values

Data Structures

- Abstract Data Types - A mathematical model for data types
    - String - A finite sequence of symbols that are chosen from a set called an alphabet
    - List - An abstract data type that represents a finite number of ordered values
    - Associative array - An abstract data type that can hold a collection of (key, value) pairs
    - Stack - An abstract data type that serves as a collection of elements, with two main operations: push and pop

  - Queue - An abstract data type that serves as a collection of elements, with two main operations: enqueue and dequeue
    - Priority queue - An abstract data type which is like a regular queue or stack data structure, but where additionally each element has a "priority" associated with it
  - Tree - An abstract data type that represents a hierarchical tree structure with a set of connected nodes
  - Graph - An abstract data type that is meant to implement the undirected graph and directed graph concepts from mathematics
    - Directed acyclic graph (DAG) - A directed graph with no directed cycles
- Data Structures - A data organization, management, and storage format that is designed to enable efficient access and modification
  - Passive data structure - A record data structure that contains only public data fields and provides no methods other than implicitly for reading/writing the fields
  - Array - A data structure consisting of a collection of elements (values or variables)
    - Array slicing - An operation that extracts a subset of elements from an array and packages them as another array
    - Sparse matrix - A matrix in which most of the elements are zero, allowing for specialized storage and algorithms to save memory and processing time
  - Hash table - A data structure that implements an associative array abstract data type
    - Collision Resolution
      - Cuckoo hashing - A scheme in computer programming for resolving hash collisions of keys in a hash table
      - Linear probing - A scheme in computer programming for resolving collisions in hash tables
  - Linked data structure - A data structure which consists of a set of data records (nodes) linked together and organized by references
  - Persistent structure - A data structure that always preserves the previous version of itself when it is modified
  - Disjoint-set data structure - A data structure that stores a collection of disjoint (non-overlapping) sets
  - Tree-based
    - Search tree - A tree data structure used for locating specific keys from within a set
      - Binary search tree (BST) - A rooted binary tree data structure with the key of each internal node being greater than all keys in the respective node’s left subtree and less than the ones in its right subtree
    - Markle tree - A tree in which every leaf node is labelled with the cryptographic hash of a data block
    - Heap - A tree-based data structure that satisfies the heap property

        - Trie - A search tree data structure used to locate specific keys from within a set
        - Fenwick tree - A data structure that can efficiently update elements and calculate prefix sums in a table of numbers
    - Graph-based
        - Adjacency matrix - A square matrix used to represent a finite graph
        - Adjacency list - A collection of unordered lists used to represent a finite graph

10 - Advanced Programming

Procedural & Systems Programming

:::note[Relevant DSS-P Skills]

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  ==== Rust Language

- Rust - A programming language that empowers everyone to build reliable and efficient software
    - Ownership and borrowing - A set of rules that govern how a Rust program manages memory
    - Interior mutability - A design pattern in Rust that allows you to mutate data even when there are immutable references to that data
    - Closure - An anonymous function you can save in a variable or pass as an argument to other functions
    - Trait-based generics - A way to define behavior that a type must provide, allowing for generic code that can operate on any type that implements the specified behavior
    - Lifetime - A construct the compiler uses to ensure all borrows are valid
    - Module Pin - A module that provides types which pin data to its location in memory
    - Tools
        - C2Rust - A tool that is able to translate most C modules into semantically equivalent Rust code
    - Tutorials
        - Rust by Example - A collection of runnable examples that illustrate various Rust concepts and standard libraries

Go Language

- Go - An open-source programming language supported by Google
    - Core Features

        - Go Modules - The dependency management system for the Go programming language
        - Defer, panic and recover - The powerful but unusual control-flow mechanisms in Go
        - Pointer receiver - A method that operates on a pointer to the type, allowing it to modify the value to which the receiver points
        - Interface - A type defined as a set of method signatures
        - Goroutine - A lightweight thread managed by the Go runtime
        - Channel - A typed conduit through which you can send and receive values with the channel operator, ←
    - Libraries
        - Awesome Go - A curated list of awesome Go frameworks, libraries, and software
        - lo - A Lodash-style Go library
        - fp-go - A collection of Functional Programming helpers
        - shortuuid - A generator library for concise, unambiguous and URL-safe UUIDs
    - Tools
        - Go binary size SVG treemap - A CLI tool to make treemaps of size of Go executable
        - mvm - A fast virtual machine for Go and beyond that enables users to run Go programs directly from source code without compilation
    - Tutorials
        - Effective Go - A document that gives tips for writing clear, idiomatic Go code
        - Go by Example - A hands-on introduction to Go using annotated example programs
        - Learn Go with tests - A resource that teaches the fundamentals of Go, including testing, on the first day

C & Other Procedural Languages

- C - A general-purpose, procedural computer programming language supporting structured programming, lexical variable scope, and recursion, with a static type system
    - Macros - A fragment of code which has been given a name
- Zig - A general-purpose programming language and toolchain for maintaining robust, optimal and reusable software
    - Comptime - The mechanism that allows you to execute code at compile-time

Functional & Hybrid Programming

:::note[Relevant DSS-P Skills]

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  ==== Functional-first & Multi-paradigm Languages

- F# - A universal programming language for writing succinct, robust and performant code
  - Immutable data structure
  - Discriminated union - A type that can store a value of one of several different, but fixed, types
  - Active pattern - A feature that lets you define named partitions that subdivide input data, so that you can use these names in a pattern matching expression
  - Computation expression - A feature that provides a convenient syntax for writing computations that can be sequenced and combined using control flow constructs and bindings
- OCaml - An industrial-strength functional programming language with an emphasis on expressiveness and safety
  - Functor - A module that is parameterized by another module
- Haskell - An advanced, purely functional programming language
  - Purely functional
  - Lazy evaluation - An evaluation strategy which delays the evaluation of an expression until its value is needed
- Elixir - A dynamic, functional language for building scalable and maintainable applications
  - Process - A lightweight thread of execution that is isolated and exchanges information via messages
- Power Fx - A low-code language used across Microsoft Power Platform that is a general-purpose, strong-typed, declarative, and functional programming language

Multi-paradigm & Hybrid Languages

- Java - The #1 programming language and development platform
  - Built-in concurrency support - The features of the Java platform designed from the ground up to support concurrent programming
- C# - A modern, object-oriented, and type-safe programming language
  - Language-Integrated Query (LINQ) - The name for a set of technologies based on the direct integration of query capabilities into the C# language
  - Delegate - A type that represents references to methods with a particular parameter list and return type
  - Lambda expression - A way to create an anonymous function
- Scala - A modern multi-paradigm programming language designed to express common programming patterns in a concise, elegant, and type-safe way

  - Hybrid OO/functional - A characteristic of a language that fuses object-oriented and functional programming in a statically typed setting
- Groovy - A powerful, optionally typed and dynamic language, with static-typing and static compilation capabilities, for the Java platform
- Dart - A client-optimized language for fast apps on any platform

Data & Format Standards

:::note[Relevant DSS-P Skills]

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  ==== Text Format & Character Code

- ASCII - A character encoding standard for electronic communication
- Unicode - The universal character encoding standard support
  - UTF-8 - A variable-width character encoding used for electronic communication
  - Unicode Emoji - A standardized set of characters that are used like emoticons
- CSV - A delimited text file that uses a comma to separate values
- TSV - A delimited text file format that uses a tab character to separate values in a table
- Libraries
  - ICU - A mature, widely used set of C/C++ and Java libraries providing Unicode and Globalization
  - Python emoji - An emoji library for Python
  - Go emoji - A minimalistic emoji package for Go

DateTime Format

- UTC - The primary time standard globally used to regulate clocks and time
- ISO 8601 - An international standard covering the worldwide exchange and communication of date- and time-related data
- Unix time - A system for describing a point in time
- Libraries
  - Ruby Time - An abstraction of dates and times
  - Python delorean - A library for clearing up the inconvenient truths that arise dealing with datetimes in Python
  - Python arrow - A Python library that offers a sensible and human-friendly approach to creating, manipulating, formatting and converting dates, times and timestamps
  - Luxon - A powerful, modern, and friendly wrapper for JavaScript dates and times

  - date-fns - A modern JavaScript date utility library that provides the most comprehensive, yet simple and consistent toolset for manipulating JavaScript dates in a browser & Node.js
  - Day.js - A minimalist JavaScript library that parses, validates, manipulates, and displays dates and times for modern browsers with a largely Moment.js-compatible API
  - Go time - A package that provides functionality for measuring and displaying time
  - Go when - A natural language date/time parser with no dependencies
- iCalendar - A media type which allows users to store and exchange calendaring and scheduling information

Data Exchange Languages

- JSON - A lightweight data-interchange format
  - jq - A lightweight and flexible command-line JSON processor
  - gojq - A Pure Go implementation of jq
  - gron - A tool that transforms JSON into discrete assignments to make it easier to grep for what you want and see the absolute 'path' to it
  - JMESPath - A query language for JSON
  - JSON::Tiny - A minimalistic JSON module with no dependencies
  - Python json - A module that implements a JSON encoder and decoder
  - Jackson - A suite of data-processing tools for Java, including a streaming JSON parser / generator library and matching data-binding library
- XML - A simple, very flexible text format derived from SGML (ISO 8879)
  - XPath - An expression language that allows the processing of values conforming to the XQuery and XPath Data Model
  - DOM - A platform-neutral model for events, aborting activities, and node trees
  - Python xml.etree.ElementTree - A module that implements a simple and efficient API for parsing and creating XML data
  - Nokogiri - A Ruby library that makes it easy and painless to work with XML and HTML, providing tools for reading, writing, modifying, and querying documents
- logfmt - A log format that is simple, fast, and easy for humans and machines to parse
- JSON Lines - A convenient format for storing structured data that may be processed one record at a time
- Related Tools
  - fx - A terminal JSON viewer
  - jnv - An interactive JSON viewer and jq filter editor designed for navigating JSON

Configuration Languages

- JSON Superset
  - Jsonnet - A data templating language for app and tool developers
  - Hjson - A user interface for JSON
  - YAML - A human-friendly data serialization language for all programming languages
    - yq (python) - A command-line YAML, XML, TOML processor and jq wrapper for YAML, XML, TOML documents
    - yq (go) - A portable command-line YAML, JSON, XML, CSV, TOML and properties processor
    - YAML::Tiny - A Perl class for reading and writing YAML-style files, written with as little code as possible
    - PyYAML - A YAML parser and emitter for Python
  - StrictYAML - A type-safe YAML parser that parses and validates a restricted subset of the YAML specification
  - JSON with comments - A JS library to parse and stringify JSONC (JSON with comments)
  - CUE - An open-source data validation language and inference engine with its roots in logic programming
- Other Configuration Languages
  - TOML - A minimal configuration file format that's easy to read
    - TOML::Tiny - A minimal, pure perl TOML parser and serializer
    - Python tomllib - A module that provides an interface for parsing TOML
  - HCL - A toolkit for creating structured configuration languages that are both human- and machine-friendly
- Related Tools
  - yj - A command-line interface tool to convert between YAML, TOML, JSON, and HCL
- General Expression Languages
  - CEL - A general-purpose expression language designed to be fast, portable, and safe to execute

Text Processing & Manipulation

:::note[Relevant DSS-P Skills]

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  ==== Regular Expression

- Regex - A sequence of characters that specifies a search pattern in text
  - PCRE - A library implementing regular expression pattern matching using the same syntax and semantics as Perl 5
  - Onigmo - A regular expressions library forked from Oniguruma
  - Python re - The module provides regular expression matching operations similar to those found in Perl
  - Go regexp - The package that implements regular expression search
  - RE2 - A fast, safe, thread-friendly alternative to backtracking regular expression engines
- PRegEx - A Python library that allows for the programmatic creation of regular expressions
- Regex Tools
  - Rubular - A Ruby-based regular expression editor
  - rubree - A Ruby regular expression editor inspired by Rubular
  - Wubular - A Javascript-based regular expression editor, inspired by Rubular
  - RegEx101 - An online regular expression editor and debugger

Text Tools

- General Tools
  - GNU sed - A stream editor used to perform basic text transformations on an input stream
  - sd - An intuitive find and replace command-line tool
  - GNU diffutils - A package of several programs for finding the differences between files
  - colordiff - A tool that produces the same output as diff but with coloured syntax highlighting to improve readability

Tabular Data

- CLI Tools
  - csvkit - A suite of command-line tools for converting to and working with CSV
  - xsv - A fast CSV command line toolkit written in Rust
  - qsv - A command line program for indexing, slicing, analyzing, splitting, enriching, transforming & joining CSV files
  - GNU awk - A program that you can use to select particular records in a file and perform operations upon them
  - GoAWK - A POSIX-compliant AWK interpreter written in Go with CSV support
- Libraries

  - Text::CSV - A comma-separated values manipulator (using XS or PurePerl)
  - Python csv - A module that implements classes to read and write tabular data in CSV format
  - Ruby csv - A complete interface to CSV files and data
  - smarter_csv - A Ruby Gem for convenient reading and writing of CSV files
  - Go csv - A package that reads and writes comma-separated values (CSV) files
  - Papa Parse - The powerful, in-browser CSV parser for JavaScript
  - Python tabulate - A library and a command-line utility that displays data in a visually appealing format
  - Text::MarkdownTable - A module that can be used to write data in tabular form, formatted in MultiMarkdown syntax
  - Terminal Table - A simple, feature-rich ascii table generation library for ruby

Template Engines

- Template Languages and Engines
  - gomplate - A fast template renderer supporting many datasources and hundreds of functions
  - Go template - A package that implements data-driven templates for generating textual output
    - sprig - A library that provides template functions for Go's template language
  - mustache - A logic-less template syntax
  - Jinja - A full-featured template engine for Python
  - Perl Text::Template - A library for generating form letters, building HTML pages, or whatever you can imagine
  - Perl HTML::Template - A system for creating HTML templates
  - Template Toolkit - A fast, flexible and highly extensible template processing system
  - ERB - An easy to use but powerful templating system for Ruby
  - Haml - A markup language that's used to cleanly and simply describe the HTML of any web document without the use of inline code
  - Liquid - A safe, customer-facing template language for flexible web apps
  - envsubst in gettext - A program that substitutes the values of environment variables

Markup & Document Processing

- unified - A friendly interface backed by an ecosystem of plugins built for creating and manipulating content
  - remark - A markdown processor powered by plugins
- markdown-it - A Markdown parser with 100% CommonMark support, extensions, and

syntax plugins

  - markdown-it-py - A Python port of the markdown-it project

- markdownify - A Python library that converts HTML to Markdown with customizable options for handling tags, formatting, and styling

Debugging

:::note[Relevant DSS-P Skills]

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- Debuggers
  - Python
    - VSCode Python extension - An extension with rich support for the Python language
    - debugpy - An implementation of the Debug Adapter Protocol for Python 3
  - Node.js
    - VSCode built-in debugger - The built-in debugger that helps you speed up your edit, compile, and debug loop
    - Node.js built-in inspector - The inspector which allows attaching Chrome DevTools to Node.js instances for debugging and profiling
  - Go
    - VSCode Go extension - An extension that provides rich language support for the Go programming language
    - Delve - A debugger for the Go programming language
  - Ruby
    - VSCode rdbg Ruby Debugger - A Ruby debugger extension that is based on debug.gem
    - debug.rb - The debugging functionality for Ruby
  - Others
    - VSCode Bash Debug - A bash debugger GUI frontend based on bashdb
    - BASH Debugger - A bash shell command-line debugger
    - GDB - The GNU Project debugger
- Debugger protocols
  - DAP - The abstract protocol used between a development tool (e.g. IDE or editor) and a debugger
  - V8 V8 Inspector Protocol - The protocol that allows for tools to instrument V8 to debug and profile JavaScript applications

Logging

- Logging Libraries
  - Python
    - Python logging - The module that defines functions and classes which implement a flexible event logging system for applications and libraries
    - loguru - A library which aims to bring enjoyable logging in Python
  - Javascript/Typescript
    - bunyan - A simple and fast JSON logging library for node.js services
    - winston - A logger for just about everything
    - debug - A tiny JavaScript debugging utility modelled after Node.js core's debugging technique
  - Go
    - Charmbracelet log - A minimal and colorful Go logging library
    - Go log - The package that implements a simple logging package
    - zap - Blazing fast, structured, leveled logging in Go
    - Logrus - A structured logger for Go (golang), completely API compatible with the standard library logger
    - Zero Allocation JSON Logger - The package that provides a fast and simple logger dedicated to JSON output
  - Others
    - logger - A tool to enter messages into the system log
    - log4j - A versatile, industrial-grade Java logging framework
    - log4sh - An advanced logging framework for shell scripts
    - log4net - A port of the excellent Apache log4j framework to the Microsoft .NET runtime

Test Frameworks & Tools

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Software Development Process

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- Test Concepts and Best Practices
  - Test Pyramid - A way of thinking about how different kinds of tests should be used to create a balanced portfolio
  - Test case - A specification of the inputs, execution conditions, testing procedure, and expected results that define a single test

    - Test double - An object that can stand in for a real object in a test
    - Unit testing best practices with .NET - A set of best practices that help you write tests that are robust and easy to maintain
    - JS Testing Best Practices - A summary of the top testing practices for JavaScript
- Test Protocols
    - Test Anything Protocol - A simple text-based interface between testing modules and a test harness
        - tappy - A set of tools for working with the Test Anything Protocol (TAP)
        - Node-Tap - A Test-Anything-Protocol library for JavaScript

Test Frameworks

- Bash
    - Bats-core - A Bash Automated Testing System
    - shUnit2 - A unit test framework for Bourne based shell scripts
    - shellspec - A full-featured BDD unit testing framework for dash, bash, ksh, zsh and all POSIX shells
- Ruby
    - Minitest - A complete suite of testing facilities supporting TDD, BDD, mocking, and benchmarking
    - RSpec - A testing tool for the Ruby programming language
    - aruba - A tool to test command-line applications with Cucumber-Ruby, RSpec or Minitest
- Python
    - Python unittest - A unit testing framework, sometimes referred to as 'PyUnit', which is a Python language version of JUnit
    - pytest - A framework that makes it easy to write small, readable tests, and can scale to support complex functional testing
    - pytest-mock - A pytest plugin that provides a `mocker` fixture which is a thin-wrapper around the standard `unittest.mock` package
- Javascript/Typescript
    - Vitest - A blazing fast unit-test framework powered by Vite
    - Jest - A delightful JavaScript Testing Framework with a focus on simplicity
    - Mocha - A feature-rich JavaScript test framework running on Node.js and in the browser
    - Runtime-integrated
        - bun test - A fast, Jest-compatible test runner built into Bun
        - deno test - A built-in test runner that you can use for testing JavaScript and

TypeScript code

- Go
  - Go testing - A package that provides support for automated testing of Go packages
  - Ginkgo - A BDD-style testing framework for Go
- Others
  - JUnit - The 5th major version of the programmer-friendly testing framework for Java and the JVM
  - xUnit.net - A free, open source, community-focused unit testing tool for the .NET Framework

Assertion Libraries

- Chai - A BDD / TDD assertion library for node and the browser
- Gomega - A matcher/assertion library for Go

Code Coverage Tools

- Go cover - A tool that provides code coverage statistics for Go programs
- Istanbul - Yet another JS code coverage tool
- cobertura - A free Java tool that calculates the percentage of code accessed by tests
- LCOV - An extension of GCOV, a GNU tool which provides information about what parts of a program are actually executed
- kcov - A code coverage tester for compiled programs

Test Supporting Tools

- Mocking Libraries
  - Jest / Vitest built-in ones
  - mock - A command-line tool for mocking HTTP responses
  - unittest.mock - A library for testing in Python that allows you to replace parts of your system under test with mock objects
  - sinon.js - A standalone and test framework agnostic JavaScript test spies, stubs and mocks
  - mockery - A project that creates mock implementations of Golang interfaces
- Test Data Generators
  - Databricks Labs Data Generator - A Python library for generating synthetic data within the Databricks environment using Spark
  - generatedata.com - A powerful, feature-rich, random test data generator
  - gofakeit - A random data generator written in go

  - Fake-rs - A library for generating fake data in Rust
- Multi-Environment Test Runners
  - nox - A command-line tool that automates testing in multiple Python environments, similar to tox
  - tox - A command-line driven automated testing tool for Python

Mutation Testing

- Mutation testing - A type of software testing where certain statements of the source code are changed to check if the test suite is able to find the errors
  - cargo-mutants - A tool for Rust that helps you improve your program's quality by finding places where bugs can be inserted without causing any tests to fail
  - Stryker Mutator - A tool to test your tests with mutants
  - PIT Mutation Testing - A state of the art system, providing gold standard test coverage for Java and the JVM

Build Automation

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Computer Science
- 3. Technology > 3.1 Software Development > Cloud Infrastructure Utilization

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- Build Automation Tools
  - GNU Make - A tool which controls the generation of executables and other non-source files of a program
    - Remake - An enahanced version of GNU Make that adds improved error reporting, better tracing, profiling and a debugger
    - makefile-graph - A Go module and CLI application, which parses GNU Make's internal database and generates a graph
  - Bazel - A fast, scalable, multi-language and extensible build system
  - Gradle - An open-source build automation tool that is designed to be flexible enough to build almost any type of software
  - Maven - A software project management and comprehension tool
  - Task - A task runner / build tool that aims to be simpler and easier to use than GNU Make
  - CMake - An open-source, cross-platform family of tools designed to build, test and package software
    - CPack - A tool to configure generators for binary installers and source packages
  - Meson - An open source build system meant to be both extremely fast, and, even

more importantly, as user friendly as possible
  - Dune - A composable build system for OCaml, OCaml-related languages, and Coq
  - Rake - A Make-like program implemented in Ruby
  - fpm - A tool which lets you easily create packages for Debian, Ubuntu, Fedora, CentOS, RHEL, Arch Linux, and more
- Tutorials
  - Makefile Tutorial by Example - A tutorial that teaches you the basics of Makefiles

Monorepo Management

- Monorepo Tools
  - Turborepo - A high-performance build system for JavaScript and TypeScript monorepos
  - Nx - A smart, fast and extensible build system with first-class monorepo support and powerful integrations
  - Lerna - The original monorepo tool for JavaScript/TypeScript
- Resources
  - Monorepo Tools - A website with tools and resources for monorepos

Program Documentation

- Program Documentation Tools
  - apiDoc - A tool that creates a documentation from API descriptions in your source code
  - JSDoc - An API documentation generator for JavaScript
  - perldoc - A tool that looks up a piece of documentation in .pod format that is embedded in the perl installation tree
    - Pod - A simple-to-use markup language used for writing documentation for Perl, Perl programs, and Perl modules
  - pydoc - A tool that automatically generates documentation from Python modules
    - Docstring - A string literal that appears as the first statement in a module, function, class, or method definition
  - godoc - A tool that extracts and generates documentation for Go programs
  - rustdoc - A tool that generates documentation for Rust projects
  - RDoc - A tool that produces HTML and command-line documentation for Ruby projects
  - Javadoc - A tool from Oracle for generating API documentation in HTML format from doc comments in source code

Package Dependency Management

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Computer Science

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- JavaScript & Web Ecosystem
  - npm CLI - The world's largest software registry
    - npm-check-updates - A command-line tool that allows you to upgrade your package.json dependencies to the latest versions
    - npmgraph - A tool for exploring the npm dependency graph
  - yarn - A package manager that doubles down as project manager
  - pNPm - A fast, disk space efficient package manager
  - dpmland - A simple, modern and easy way to manage the Deno modules and dependencies
  - Bun package manager - A fast, npm-compatible package manager built into Bun
  - orogene - A next-generation package manager for the JavaScript ecosystem
- Python Development
  - pip - The package installer for Python
  - poetry - A tool for dependency management and packaging in Python
  - pdm - A modern Python package and dependency manager supporting the latest PEP standards
  - uv - An extremely fast Python package and project manager, written in Rust
- Systems & Native Languages
  - go mod - A tool for managing Go source code
  - Cargo - The Rust package manager
  - Conan - A dependency and package manager for C and C++ languages
  - vcpkg - A free C/C++ package manager for acquiring and managing libraries
  - bpkg - A lightweight bash package manager
- JVM & .NET Frameworks
  - Maven - A software project management and comprehension tool
  - Gradle - An open-source build automation tool that is designed to be flexible enough to build almost any type of software
  - NuGet CLI - The package manager for .NET
- Other Language Ecosystems
  - RubyGems CLI - The official package manager for Ruby

  - Bundler - A tool that provides a consistent environment for Ruby projects
  - LuaRocks CLI - The package manager for Lua modules
  - cpanminus - A tool to get, unpack, build and install modules from CPAN
  - stack - A cross-platform program for developing Haskell projects
  - opam - A source-based package manager for the OCaml community
  - Pub - The official package manager for Dart and Flutter
  - Hex - The package manager for the Erlang ecosystem

Virtual Environment

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Computer Science

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- Virtual Environment Managers
  - Python venv - A module for the creation of virtual environments
  - pyenv - A tool for simple Python version management
  - nodeenv - A tool to create isolated node.js environments
  - nvm - A POSIX-compliant bash script to manage multiple active node.js versions
  - nvm-windows - A node.js version manager for Windows
  - rv - A simple and powerful Ruby version manager written in Rust
  - frum - A fast and modern Ruby version manager written in Rust
  - perlbrew - A tool to manage multiple perl installations in your $HOME directory
  - asdf - A tool version manager
  - mise - A polyglot tool version manager
  - tenv - A versatile version manager for OpenTofu, Terraform, Terragrunt and Atmos

11 - Specialized Development Domains

Business & Productivity Application SDKs

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Service Utilization

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  ==== Project & Work Management
- Python Jira - A Pythonic interface to the JIRA REST APIs

- Notion SDK for JavaScript - An official client for the Notion API
- Linear SDK - A typed TypeScript SDK for interacting with Linear's GraphQL API for planning and building products
- Asana Python SDK - The official Python client library for the Asana API that provides programmatic access to Asana's project management platform
- py-trello - A Python API wrapper that represents Trello objects (boards, lists, cards) as corresponding Python objects with cached attributes

Collaboration & Communication

- Python Slack SDK - A software development kit that helps Python developers build apps that integrate with Slack
- Slack API in Go - A Go library for the Slack API
- discord.js - A powerful Node.js module that allows you to interact with the Discord API very easily
- Microsoft Teams JavaScript client library - A library that helps you create hosted experiences in Teams, Microsoft 365 app, and Outlook, where your app content is hosted in an iFrame
- Notify - A dead simple Go library for sending notifications to various messaging services
- Twilio Node.js SDK - The official Node.js helper library for the Twilio API, providing developers with tools to integrate Twilio's communication services
- Zoom Meeting SDK - A WebAssembly-based SDK that embeds Zoom Meeting and Webinar experiences in web applications with support for Angular, React, and Vue.js

Cloud Storage & File Management

- Dropbox JavaScript SDK - The official Dropbox SDK for JavaScript that provides API V2 access for Node.js and browser applications with OAuth support and TypeScript compatibility
- Box Node SDK - A JavaScript interface for interacting with the Box API that provides complete coverage of Box's API ecosystem with features including authentication methods and automatic retries
- Airtable.js - The official JavaScript library that provides a simple way to access and interact with your Airtable data through its RESTful API

Email & Marketing Automation

- SendGrid Node.js SDK - The official Twilio SendGrid Node.js API library for quickly and easily using the SendGrid Web API v3
- Mailchimp Marketing Node.js SDK - The official Node.js client library for the Mailchimp Marketing API that supports authentication via Basic Auth or OAuth2

Payments & Finance

- Stripe Node.js SDK - A library that provides convenient access to the Stripe API from server-side JavaScript applications with TypeScript support and automatic retries

CRM & Customer Support

- JSforce - A Salesforce API library for JavaScript applications
- HubSpot Node.js SDK - An official SDK that provides access to HubSpot's V3 API for managing CRM objects, files, OAuth, and other platform features
- node-zendesk - A trusted API client library for Node.js and the browser that provides seamless integration with Zendesk's Customer Support Platform

Enterprise Workspaces

- Microsoft 365 Development
  - PnPjs - A collection of fluent libraries for consuming SharePoint, Graph, and Office 365 REST APIs
  - SharePoint Framework (SPFx) - A page and web part model that provides full support for client-side SharePoint development, easy integration with SharePoint data, and extending Microsoft Teams and Microsoft Viva
  - CLI for Microsoft 365 - A cross-platform command line interface that enables you to manage your Microsoft 365 tenant and SharePoint Framework projects on any platform
  - Microsoft Graph - The gateway to data and intelligence in Microsoft 365
  - Work-IQ - An MCP (Model Context Protocol) server and CLI for accessing Microsoft 365 data
- Google Workspace Development
  - Google Workspace CLI - A command-line tool for Drive, Gmail, Calendar, Sheets, Docs, Chat, Admin, and more, dynamically built from Google Discovery Service and including AI agent skills
  - Google APIs Node.js Client - A Node.js client library for using Google APIs with support for OAuth 2.0, API Keys, and JWT token authentication

Developer Tools Integration SDKs

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Team Development

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  ==== Version Control & DevOps

- Octokit.js - The all-batteries-included GitHub SDK for Browsers, Node.js, and Deno

- PyGithub - A Python library that enables you to manage GitHub resources such as repositories, user profiles, and organizations through the GitHub REST API
- go-github - A Go client library for accessing the GitHub v3 REST API, providing comprehensive coverage of GitHub's endpoints
- python-gitlab - A wrapper for the GitLab API written in Python
- GitLab Go Client - An official Go library for interacting with the GitLab API, providing comprehensive support for GitLab resources
- GitLab Ruby Gem - A Ruby wrapper and CLI for the GitLab REST API that allows developers to interact with GitLab programmatically
- Atlassian Python API - A Python library that provides a simple wrapper for interacting with Atlassian product REST APIs including Jira, Confluence, and Bitbucket

Container & Orchestration

- Docker SDK for Python - A Python library for the Docker Engine API that lets you do anything the docker command does from within Python applications
- Docker SDK for Go - The official Go client for the Docker Engine API
- Kubernetes client-go - The official Go client library for interacting with Kubernetes clusters, providing clientsets, dynamic clients, and controller-building tools
- Kubernetes Python Client - The official Python library for interacting with the Kubernetes API, enabling programmatic cluster management and resource operations

CI/CD & Automation

- python-jenkins - A Python wrapper for the Jenkins REST API that provides a conventionally pythonic way to control and automate Jenkins servers
- GitHub Actions Toolkit - A set of packages that provides functions and utilities to make creating GitHub Actions easier, including features for inputs/outputs and file operations
- Terraform Plugin SDK - A framework that enables building Terraform plugins (providers) to manage service providers and custom in-house solutions

Computer Graphics & Game Development

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Front-end System Development

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  ==== 3D Graphics

- Three.js - A JavaScript 3D library that makes it easy to create and display animated 3D computer graphics in a web browser using WebGL
- GSAP - A robust JavaScript toolset that turns developers into animation superheroes

2D Graphics

- PixiJS - An advanced, open-source 2D rendering engine designed for creating stunning visual experiences on the web

Graphics APIs

- WebGL - A cross-platform, royalty-free web standard for a low-level 3D graphics API based on OpenGL ES
- OpenGL - A cross-language, cross-platform application programming interface for rendering 2D and 3D vector graphics
- Vulkan - A low-overhead, cross-platform, 3D graphics and computing API
  - nvk - Vulkan headers for the Go programming language

Binary & Media Processing

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Back-end System Development

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  ==== Binary Format Tools

- file (command) - A file type guesser
- hexdump - A filter which displays the specified files, or the standard input, in a user specified format
- xxd - The well-known hex-dump-type utility
- bed - A binary editor written in Go
- fq - A tool inspired by jq that lets you poke at binary formats
- ELF format - A common standard file format for executable files, object code, shared libraries, and core dumps

Data Serialization

- Protobuf - A language-neutral, platform-neutral, extensible mechanism for serializing structured data
- MessagePack - An efficient binary serialization format

Image & Media Formats

- JPEG - A commonly used method of lossy compression for digital images
- PNG - A raster-graphics file format that supports lossless data compression
- Webp - A raster graphics file format developed by Google intended as a replacement for JPEG, PNG, and GIF file formats

- MPEG-4 - A method of defining compression of audio and visual digital data
- High Efficiency Video Coding - A video compression standard, designed as a successor to the widely used Advanced Video Coding (AVC)

Image & Media Processing

- Tools
  - Swatchify - A tool that uses k-means clustering to extract dominant colors from images
  - exiftool - A command-line application and Perl library for reading and writing meta information in files
  - ImageMagick - A free, open-source software suite, used for editing and manipulating digital images
  - FFmpeg - A complete, cross-platform solution to record, convert and stream audio and video
- Libraries
  - go-mp4 - A Go library that provides low-level I/O interfaces for MP4
  - Native WebP for Go - A native WebP encoder written entirely in Go, with no dependencies on libwebp or other external libraries
  - Pillow - The friendly PIL (Python Imaging Library) fork that adds image processing capabilities to your Python interpreter
  - pure_jpeg - A pure Ruby JPEG encoder and decoder library with no native dependencies

Compression & Archiving

- Tools
  - GNU Gzip - A popular data compression program
  - GNU tar - A program that provides the ability to create tar archives, as well as various other kinds of manipulation
  - Info-Zip - A set of open-source software for handling ZIP archives
  - P7ZIP - A port of 7za.exe for POSIX systems
- Libraries
  - Python Data Compression and Archiving libs - The modules that support data compression and the creation and reading of archives
  - Go compress libs - A package that defines a common interface to compression and decompression algorithms
  - Go archive libs - A package that defines a common interface for accessing archived file formats
  - JSZip - A javascript library for creating, reading and editing .zip files

  - Ruby module Zlib - A module that contains classes for compressing and decompressing streams, and for working with gzip-format files
  - zlib - A free, general-purpose, legally unencumbered lossless data-compression library for use on virtually any computer hardware and operating system
  - zlib-rs - A safer zlib
  - snappy - A compression/decompression library that aims for very high speeds and reasonable compression
  - rubyzip - A ruby library for reading and writing zip files

Document Processing

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Back-end System Development

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  ==== Business Document Formats

- PDF - A file format developed by Adobe to present documents in a manner independent of application software, hardware, and operating systems
- PDF/A - An ISO-standardized version of the Portable Document Format (PDF) specialized for use in the archiving and long-term preservation of electronic documents
- Office Open XML - A zip-based XML-based file format for representing spreadsheets, charts, presentations and word processing documents
- OpenDocument - A zip-compressed, XML-based file format for spreadsheets, charts, presentations and word-processing documents

PDF Processing

- Tools
  - Docling - A powerful library which simplifies document processing, parsing diverse formats
  - Ghostscript - A suite of software based on an interpreter for Adobe Systems' PostScript and Portable Document Format page description languages
  - qpdf - A command-line tool and C++ library that performs content-preserving transformations on PDF files
  - pdftk server - A command-line tool for working with PDFs
  - pdfcpu - A PDF processor written in Go
  - MinerU - A high-quality tool for convert PDF to Markdown and JSON
  - Nano-PDF - A command-line tool that enables users to edit PDF slides using natural language instructions, powered by AI vision models, with multi-page parallel editing and non-destructive text-layer preservation through OCR

- Libraries
  - Folio - A modern PDF library for Go that includes a layout engine, HTML-to-PDF conversion, support for forms, digital signatures, barcodes, and PDF/A compliance
  - Poppler - A PDF rendering library based on the xpdf-3.0 code base
  - PDF.js - A general-purpose, web standards-based platform for parsing and rendering PDFs
  - pypdf - A pure-python PDF library capable of splitting, merging, cropping, and transforming the pages of PDF files
  - PyMuPDF - A high-performance Python library for data extraction, analysis, conversion & manipulation of PDF (and other) documents
  - pdfplumber - A Python library to plumb a PDF for detailed information about each text character, rectangle, and line, plus table extraction and visual debugging
  - Prawn PDF - A fast, nimble PDF generator for Ruby
  - ReportLab - The Open Source Python library for generating PDFs and graphics

Office Document Processing

- Tools
  - libreoffice cli - The command-line interface for the LibreOffice office suite
  - markitdown - A lightweight Python utility for converting various files to Markdown for use with LLMs and related text analysis pipelines
  - xlsx2csv - A fast and easy way to convert XLSX files to CSV
  - docx2txt - A pure python-based command line tool to extract text from docx files
  - pptx2md - A simple tool for converting pptx to markdown
- Libraries
  - python-pptx - A Python library for creating and updating PowerPoint (.pptx) files
  - PptxGenJS - A JavaScript library for building PowerPoint presentations that works with Node.js, React, and web browsers
  - Excelize - A Go library for reading and writing XLSX/XLSM/XLTM files
  - Roo - A library that can access the contents of various spreadsheet files

CLI/TUI Development

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Computer Science
- 3. Technology > 3.1 Software Development > Team Development

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- Bash

  - built-in getopts etc. - A set of commands that are part of the shell itself
  - tput - A command to initialize a terminal or query the terminfo database
  - dialog - A program that can be used to create nice user interfaces for shell scripts
  - Gum - A tool for glamorous shell scripts
  - FIGlet - A program for making large letters out of ordinary text
  - lolcat - A program that concatenates files, or standard input, to standard output and adds rainbow coloring
  - cfonts - A tool to print sexy fonts in your console
- Perl
  - Getopt::Long - A module that implements an extended getopt function called GetOptions()
  - Term::ANSIColor - A module to colorize text using ANSI escape sequences
  - Text::ANSITable - A module to create a formatted table using ASCII characters and ANSI colors
- Python
  - argparse - The module for parsing command-line arguments
  - getopt - The C-style parser for command line options
  - click - A Python package for creating beautiful command line interfaces in a composable way with as little code as necessary
  - Colorama - A simple cross-platform API for printing colored terminal text from Python
  - Typer - A library for building CLI applications that users will love using and developers will love creating
  - Asciimatics - A package that provides a cross-platform, full-screen terminal API for building text-based user interfaces
  - Python Prompt Toolkit - A library for building powerful interactive command line and terminal applications in Python
  - Questionary - A Python library for building interactive command line prompts
  - Urwid - A console user interface library for Python
  - Textual - A Rapid Application Development framework for Python, built by Textualize.io
    - Rich - A Python library for rich text and beautiful formatting in the terminal
- Ruby
  - OptionParser - A class for command-line option analysis
  - colorize - A gem for colorizing text using ANSI escape sequences
  - TTY - A suite of gems that provide a wide range of tools for building interactive command-line applications
  - thor - A toolkit for building powerful command-line interfaces

  - dry-cli - A general-purpose framework for developing Command Line Interface (CLI) applications that represents commands as objects and offers support for arguments, options, and forwarding variadic arguments to sub-commands
  - Clamp - A minimal framework for command-line utilities that handles parsing command-line arguments and generating help
- Javascript
  - yargs - A library for building interactive command line tools by parsing arguments and generating an elegant user interface
  - minimist - A tool to parse argument options
  - chalk - A terminal string styling tool
  - cli-progress - An easy to use progress-bar for command-line/terminal applications
  - FIGLet.js - A FIG Driver written in JavaScript which aims to fully implement the FIGfont spec
  - Ink - A React-based library for building CLI applications
  - gradient-string - A library for creating beautiful gradients in terminal output
- Go
  - Fang - The CLI starter kit. A small, experimental library for batteries-included Cobra applications
  - Bubble Tea - A Go framework for building terminal apps based on The Elm Architecture
    - Lip Gloss - A declarative library for defining styles and layouts in terminal applications
    - Bubbles - A collection of common terminal user interface components
  - Huh - A simple, powerful, and elegant TUI library for building terminal forms and prompts
  - pflag - A drop-in replacement for Go's flag package, implementing POSIX/GNU-style --flags
  - color - A package for Go that lets you use colorized outputs in terms of ANSI escape sequences
  - Cobra - A framework for creating powerful modern CLI applications
  - urfave/cli - A simple, fast, and fun package for building command line apps in Go
  - viper - A complete configuration solution for Go applications
  - Wish - A tiny SSH server for your programs
  - Wishlist - An SSH directory for your private hostkeys and favorite SSH commands
  - go-tui - A framework for building declarative terminal user interfaces (TUIs) in Go
- Rust
  - clap - A full featured, fast Command Line Argument Parser for Rust

  - Ratatui - A Rust library for cooking up delicious terminal user interfaces
  - R3BL - A suite of libraries for building modern terminal apps with Rust
  - Ansic - A modern, efficient and compile time ansi macro and utilities crate for Rust
- C
  - ncurses - A programming library providing an application programming interface (API) that allows the programmer to write text-based user interfaces in a terminal-independent manner

Desktop App Development

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Front-end System Development

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  ==== Client OS & Environments

- Windows Environment
  - Package Management & Administration
    - Chocolatey - The package manager for Windows
    - Scoop - A command-line installer for Windows
    - WinGet - A command line tool enabling users to discover, install, upgrade, remove and configure applications on Windows
    - gsudo - A Sudo for Windows, with a similar user-experience to the original Sudo
  - Productivity & Automation
    - AutoHotKey - A free, open-source scripting language for Windows that allows users to easily create small to complex scripts
    - Clavier+ - Allows to trigger actions with keyboard shortcuts
    - WinSSHTerm - A tabbed SSH solution for Windows, combining PuTTY, WinSCP and VcXsrv
- Android on Linux
  - Waydroid - A container-based approach to boot a full Android system on regular GNU/Linux systems running Wayland based desktop environments

GUI Systems & Windowing

- Display Servers
  - X.org - An open source implementation of the X Window System
  - Wayland - A replacement for the X11 window system protocol and architecture
- Desktop Environments

    - GNOME - An easy and elegant way to use your computer, designed to put you in control and get things done
    - Xfce - A lightweight desktop environment for UNIX-like operating systems
- Window Managers
    - openbox - A highly configurable, next generation window manager

Desktop GUI Toolkits

- Standard Toolkits
    - Tk - A graphical user interface toolkit
        - tkinter - The standard Python interface to the Tcl/Tk GUI toolkit
        - CustomTkInter - A python UI-library based on Tkinter, which provides new, modern and fully customizable widgets
    - GTK - A free and open-source cross-platform widget toolkit for creating graphical user interfaces
        - pygobject - A set of Python bindings for the GLib, GObject, GIO and GTK object-oriented C libraries
- Compiled & Canvas-Based (Custom Rendering)
    - Slint - A declarative GUI toolkit to build native user interfaces for Rust, C++, or JavaScript apps
    - Gio - A library for writing cross-platform immediate mode GUI-s in Go
    - Fyne - An easy to learn toolkit for creating graphical apps for desktop, mobile and web
- Web-Technology Based
    - Chromium Bundling
        - Electron - A framework for building desktop applications using JavaScript, HTML, and CSS
    - System WebView (Hybrid)
        - Tauri - A toolkit that helps developers make applications for the major desktop platforms
        - Wails - A tool that enables developers to build desktop applications using Go and web technologies
        - Microsoft Edge WebView2 - A control that allows you to embed web technologies (HTML, CSS, and JavaScript) in your native apps by using Microsoft Edge as the rendering engine

Installation & Packaging

- NSIS - A professional open source system to create Windows installers
- PyInstaller - A tool that bundles a Python application and all its dependencies into a

single package

Mobile App Development

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Front-end System Development

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  ==== Mobile Platforms & Native SDKs

- Android - A mobile operating system based on a modified version of the Linux kernel and other open-source software
  - Android Studio - The official integrated development environment for Google's Android operating system
- iOS - A mobile operating system created and developed by Apple Inc. exclusively for its hardware

Mobile Cross-Platform Frameworks

- Canvas-Based (Custom Rendering)
  - Flutter - An open-source UI software development kit created by Google
- Native Widget Brigde
  - React Native - A framework for building native apps with React
    - Expo - A framework and a platform for universal React applications that run natively on Android, iOS, and the web
  - .NET MAUI - A cross-platform framework for creating native mobile and desktop apps with C# and XAML
- Web-Technology Based
  - Capacitor - A cross-platform native runtime that makes it easy to build performant mobile apps, desktop apps, and Progressive Web Apps
  - Ionic Framework - An open source UI toolkit for building performant, high-quality mobile and desktop apps using web technologies

Mobile DevOps & Testing

- fastlane - The easiest way to automate beta deployments and releases for your iOS and Android apps
- Appium - An open source test automation framework for use with native, hybrid and mobile web apps

Application Services & Features

- Notifications
  - Firebase Cloud Messaging - A cross-platform messaging solution that lets you reliably send messages at no cost
  - Apple Push Notification service - The service for propagating push notifications from a developer's server to their apps on Apple devices
- Device Hardware/OS Integration
  - GPS - A satellite-based radionavigation system owned by the United States government and operated by the United States Space Force
  - QR code - A type of matrix barcode invented in 1994 by the Japanese company Denso Wave
    - libqrencode - A fast and compact QR Code encoding library
    - Pure python QR Code generator - A library that provides a simple way to create QR codes in Python
    - QR code payment - A contactless payment method where a payment is performed by scanning a QR code from a mobile app
- Backend-as-a-Service (BaaS)
  - Firebase - An app development platform that helps you build and grow apps and games users love
  - Supabase - A Postgres development platform that provides a database, authentication, instant APIs, edge functions, real-time subscriptions, storage, and vector embeddings
  - AWS Amplify - A complete solution that lets frontend web and mobile developers easily build, ship, and host full-stack applications on AWS

Internet of Things (IoT)

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.2 Digital Technology > Physical Computing

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  ==== IoT Concepts

- Internet of things (IoT) - The network of physical objects—'things'—that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the Internet
- Edge computing - A distributed computing paradigm that brings computation and data storage closer to the sources of data
- Machine to machine - The direct communication between devices using any communications channel, including wired and wireless

- Firmware - A specific class of computer software that provides the low-level control for a device's specific hardware
- Over-the-air update - The wireless delivery of new software, firmware, or other data to mobile devices

Communication Standards

- Wi-Fi - A family of wireless network protocols, based on the IEEE 802.11 family of standards, which are commonly used for local area networking of devices and Internet access
- Bluetooth Low Energy - A wireless personal area network technology designed to provide considerably reduced power consumption and cost while maintaining a similar communication range to classic Bluetooth
- Zigbee - An IEEE 802.15.4-based specification for a suite of high-level communication protocols used to create personal area networks with small, low-power digital radios
- Near-field communication - A set of communication protocols that enables communication between two electronic devices over a distance of 4 cm (1+1¬2 in) or less

IoT Hardware Platforms

- Raspberry Pi - A small, affordable computer for you to use and learn with
- Arduino - An easy-to-use, open-source hardware and software platform that enables innovation and creativity in electronics projects
- ESP32 - A feature-rich microcontroller unit with integrated Wi-Fi and Bluetooth connectivity, designed for IoT applications with ultra-low power consumption
- ESP8266 - A cost-effective and highly integrated Wi-Fi MCU for IoT applications featuring a 32-bit Tensilica processor with low power consumption
- BeagleBone - A low-cost, community-supported development platform featuring a 1GHz ARM Cortex-A8 processor that boots Linux in under 10 seconds
- STM32 - A family of 32-bit microcontrollers based on Arm Cortex-M processors designed to offer high performance, real-time capabilities, and low-power operation
- Nordic nRF52 - A family of Bluetooth Low Energy System-on-Chips built around 64 MHz ARM Cortex-M4 processors that support multiprotocol wireless connectivity
- Particle - An integrated IoT platform-as-a-service that provides edge-to-cloud infrastructure for developing, connecting, and managing intelligent devices
- BBC micro:bit - A pocket-sized programmable computer designed to inspire children to create their best digital future through hands-on coding and creative technology projects
- Teensy - A compact USB-based microcontroller development board compatible with Arduino software and capable of implementing many project types
- Adafruit Feather - A family of compact, portable microcontroller boards designed as a standard for embedded projects with built-in battery connectors and modular expansion

capabilities

IoT Cloud Platforms

- Azure IoT Hub - A managed cloud-based service that serves as a central message hub for communication between an IoT application and its connected devices
- AWS IoT Core - A managed cloud service that enables you to easily and securely connect devices to the cloud and manage device fleets at scale
- AWS IoT Greengrass - An open-source edge runtime and cloud service for building, deploying, and managing device software
- ThingWorx - A comprehensive industrial IoT application development platform designed to help organizations connect devices, analyze data, and deliver real-time insights through customizable applications
- Balena - A container-based IoT device management platform that enables developers to build, deploy, manage, and scale fleets of Linux devices with secure OTA updates and remote access
- Arduino Cloud - An all-in-one IoT platform that enables users to build, control, and monitor connected projects from anywhere with dashboards and remote access
- ThingSpeak - An IoT analytics platform service that allows you to aggregate, visualize, and analyze live data streams in the cloud with MATLAB integration
- Losant - An enterprise IoT platform that enables organizations to build scalable connected solutions by collecting, integrating, and visualizing data from devices and systems in real-time
- Adafruit IO - The easiest way to get your projects onto the Internet of Things, serving as a platform for web-based microcontroller interaction and datalogging
- ThingsBoard - An open-source IoT platform for data collection, processing, visualization, and device management that enables device connectivity via industry standard protocols
- Ubidots - A cloud-based Industrial IoT platform that enables businesses to connect, monitor, visualize, and act on sensor data in real-time through customizable dashboards and automated workflows

Low-Code & No-Code Development

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Service Utilization

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  ==== Business Application Platforms

- Microsoft Power Apps - A platform to rapidly and efficiently build professional-grade apps for any device
- AppSheet - The no-code platform that helps build powerful applications and automations to boost productivity

- OutSystems - A high-performance low-code platform that accelerates the development of critical enterprise applications

Workflow & Integration Automation

- n8n - A fair-code licensed workflow automation tool that combines AI capabilities with business process automation
- Microsoft Power Automate - An end-to-end automation solution built for enterprise to optimize business processes
- Zapier - A tool that allows you to connect your apps and automate workflows without any coding knowledge
- Microsoft Copilot Studio - A graphical low-code tool for creating and maintaining copilots using generative AI and a library of prebuilt connectors and actions

Web Content & Portal Builders

- Microsoft Power Pages - A platform to quickly create enterprise-grade AI-driven business portals with built-in agents
- Webflow - A browser-based design tool that gives you the power to build production-ready websites without coding

12 - Personal Skills

Foundational Thinking & Logic

:::note[Relevant DSS-P Skills]

- 5. Personal Skill > 5.2 Conceptual Skill > Creative Problem Solving
- 5. Personal Skill > 5.2 Conceptual Skill > Critical Thinking

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==== Logic

- Logic - The study of correct reasoning
  - Logical reasoning - A mental activity that aims to arrive at a conclusion in a rigorous way
    - Deductive, Inductive, Abductive and Analogical
- Branches of Logic
  - Informal Logic - A broad term for any of the various methods of analyzing and evaluating arguments used in everyday life

Informal Logic

- Argument - The central object of study in informal logic; a series of statements

(premises) intended to determine the degree of truth of another statement (the conclusion)

  - Enthymeme - An argument in which one premise is not explicitly stated, a common feature of real-world reasoning

- Criteria for Argument Evaluation
  - Fallacy - The use of invalid or otherwise faulty reasoning in the construction of an argument that may appear to be well-reasoned if unnoticed
  - Category mistake - An error in reasoning where a property is ascribed to a thing that could not possibly have that property
- Related Fields
  - Rhetoric - The art of persuasion
  - Critical Thinking - The process of analyzing available facts, evidence, observations, and arguments to make sound conclusions or informed choices

Mathematical Logic

:::note[Relevant DSS-P Skills]

- 5. Personal Skill > 5.2 Conceptual Skill > Critical Thinking

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  ==== Foundational Concepts

- Formal system - An abstract structure and formalization of an axiomatic system used for deducing, using rules of inference, theorems from axioms by a set of inference rules
- Gödel's incompleteness theorems - The two theorems of mathematical logic that demonstrate the inherent limitations of every formal axiomatic system capable of modelling basic arithmetic
- Logic Principles
  - De Morgan's laws - A pair of transformation rules that are both valid rules of inference
  - Law of noncontradiction - The law that states that for any given proposition, the proposition and its negation cannot both be simultaneously true
  - Law of excluded middle - The principle that for every proposition, either this proposition or its negation is true
  - Peirce's law - The principle in classical logic that the law of excluded middle holds for any proposition
  - Proof by contradiction - A form of indirect proof that establishes the truth of a proposition by showing that assuming the proposition to be false leads to a contradiction

Logical Systems

- Propositional calculus - A branch of logic that deals with propositions (which can be true or false) and relations between propositions, including the construction of arguments based on them
  - conjunction, disjunction, implication, biconditional and negation
  - Tautology - A formula that is true regardless of the interpretation of its component terms, with only the logical constants having a fixed meaning
- First order logic - A collection of formal systems used in mathematics, philosophy, linguistics, and computer science
  - universal quantification and existential quantification
- Higher order logic - A form of logic that is distinguished from first-order logic by additional quantifiers and, sometimes, stronger semantics
- Modal logic - A type of logic that is used to represent statements about possibility and necessity

Branches of Mathematical Logic

- Set theory - The branch of mathematical logic that studies sets, which can be informally described as collections of objects
- Naive set theory
  - Set - A collection of different things; these things are called elements or members of the set and are typically mathematical objects of any kind
  - Function (a.k.a. Map) - A binary relation between two sets that associates every element of the first set to exactly one element of the second set
  - Operation - A function from a set to itself
    - Idempotence - The property of certain operations in which they can be applied multiple times without changing the result beyond the initial application
  - Partition of a set - A grouping of a set’s elements into non-empty, disjoint subsets (called "blocks" or "cells") such that every element is in exactly one subset
  - Equivalence relation - A binary relation (reflexive, symmetric, and transitive) that partitions a set into disjoint equivalence classes
- Axiomatic set theory
  - Zermelo–Fraenkel set theory - An axiomatic system that was proposed in the early twentieth century in order to formulate a theory of sets free of paradoxes such as Russell’s paradox
    - Ordinals & Cardinals
- Type Theory - A formal system that provides an alternative foundation for mathematics (like Set Theory) and is the basis for typed functional programming and proof assistants.
  - Curry-Howard correspondence - The direct relationship between computer programs and mathematical proofs

- Proof Theory - A major branch of mathematical logic that represents proofs as formal mathematical objects, facilitating their analysis by mathematical techniques
  - Sequent calculus - A deductive system for proving theorems
  - Natural deduction - A kind of proof calculus in which logical reasoning is expressed by inference rules closely related to the "natural" way of reasoning
- Computability Theory - A branch of mathematical logic, computer science, and the theory of computation that originated in the 1930s with the study of computable functions and Turing degrees
  - Lambda calculus - A formal system in mathematical logic for expressing computation based on function abstraction and application
  - Turing machine - A mathematical model of computation describing an abstract machine that manipulates symbols on a strip of tape according to a table of rules
- Model Theory - The study of the relationship between formal theories (collections of sentences in a formal language) and their models (structures in which the sentences are true)
- Logic Applications
  - Constraint satisfaction problem - Mathematical questions defined as a set of objects whose state must satisfy a number of constraints or limitations
  - Satisfiability modulo theories - The problem of determining whether a mathematical formula is satisfiable
  - Automated theorem proving - A subfield of automated reasoning and mathematical logic dealing with proving mathematical theorems by computer programs
  - Formal verification - the act of proving or disproving the correctness of a system with respect to a certain formal specification or property, using formal methods of mathematics
    - Hoare logic - A formal system with a set of logical rules for reasoning rigorously about the correctness of computer programs
- Formal Logic Tools
  - Stanford Encyclopedia of Philosophy - A reference work that organizes scholars in philosophy and related fields from around the world to create and maintain up-to-date content
  - SMT-LIB - A command language for interacting with SMT solvers via a textual interface
  - MiniZinc - A free and open-source constraint modeling language
  - P - A state machine based programming language for formally modeling and specifying complex distributed systems
  - Lean - An interactive theorem prover and programming language based on the Calculus of Constructions

Documentation & Knowledge Management

:::note[Relevant DSS-P Skills]

- 3. Technology > 3.1 Software Development > Team Development
- 5. Personal Skill > 5.1 Human Skill > Collaboration

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- Technical writing - A type of writing where the author is writing about a particular subject that requires direction, instruction, or explanation
- Divio Documentation System - A framework that proposes that all documentation should be explicitly structured according to its purpose, into four distinct types: tutorials, how-to guides, technical reference and explanation

Knowledge Management

- Personal Knowledge Management
  - Obsidian - A free and flexible application for private thoughts, allowing users to store notes on their device, connect ideas, and organize knowledge with a customizable interface through plugins and themes
  - Zettelkasten - A system of note-taking and personal knowledge management for research, study, and writing, consisting of small, interconnected items of information stored on slips or cards
  - Memos - An open-source, self-hosted note-taking tool built for quick capture that is markdown-native and lightweight
- Content Management Systems (CMS)
  - Content management system - A computer software used to manage the creation and modification of digital content
  - SharePoint - A web-based collaboration and document management platform that enables organizations to securely store, share, and manage content
  - Nextcloud - The industry-leading, fully open-source, on-premise content collaboration platform
  - WordPress - A free and open-source content management system written in hypertext preprocessor language and paired with a MySQL or MariaDB database with supported HTTPS
- Wiki Systems
  - Wiki software - A collaborative software that runs a wiki, which allows users to create and collaboratively edit pages or entries via a web browser
  - MediaWiki - A free and open-source wiki software
  - Ibis - A federated encyclopedia which uses the ActivityPub protocol, just like Mastodon or Lemmy
  - Outline - The knowledge base platform that helps teams organize documents,

collaborate in real-time, and search across their workspace with AI-powered question answering

Architectural Documentation

- Diagramming Tools
  - draw.io - A technology stack for building diagramming applications, and the world's most widely used browser-based end-user diagramming software
- Diagramming as Code
  - D2: Declarative Diagramming - A modern diagram scripting language that turns text to diagrams
  - Diagrams - A Python package for drawing cloud system architectures in Python code
  - PlantUML - A tool that allows you to create diagrams from a simple textual description
  - Mermaid - A Javascript based diagramming and charting tool that renders Markdown-inspired text definitions to create and modify diagrams dynamically
  - Kroki - A free and open source service that converts plain text diagrams to images
  - Graphviz - An open source graph visualization software
    - DOT language - A plain text graph description language
    - sfdp - A scalable, multiscale force-directed layout engine for large undirected graphs that minimizes edge crossings and avoids node overlaps
    - haphviz - A Haskell library for representing, manipulating, and pretty-printing graphs in the DOT format
  - ditaa - A small command-line utility that can convert diagrams drawn using ascii art into proper bitmap graphics
- Architectural Decision Records
  - Architectural Decision Records (ADRs) - A document that captures an important architectural decision made along with its context and consequences
    - adr-tools - A command-line tool to help you manage your architectural decision records

Lightweight Markup & Writing Styles

- Lightweight Markup
  - Markdown - A lightweight markup language for creating formatted text using a plain-text editor
    - CommonMark - A rationalized version of Markdown syntax, with a spec and BSD-licensed reference implementations in C and JavaScript
    - GFM (GitHub Flavored Markdown) - A formal specification, based on the CommonMark Spec, that defines the syntax and semantics of GitHub's dialect of Markdown

        - github-markdown-css - The CSS that styles markdown rendered on GitHub
    - markdownlint - A Node.js style checker and lint tool for Markdown/CommonMark files
    - Glow - A terminal based markdown reader
    - mdterm - A terminal-based Markdown viewer written in Rust that renders Markdown files with syntax highlighting, styled formatting, and interactive navigation
    - Grip - A command-line server application that renders local README files before you push them to GitHub
    - markmap - A combination of Markdown and mindmap
    - Marp - The simplest Markdown presentation writer with plain Markdown
        - Markdown all-in-one - An all-in-one tool for Markdown (keyboard shortcuts, table of contents, auto preview, and more)
        - Markdown Preview Enhanced - A SUPER POWERFUL markdown extension for Visual Studio Code
        - Markdown Preview for (Neo)vim - A markdown preview plugin for (neo)vim
    - Guides
        - Markdown Guide - A free and open-source reference guide that explains how to use Markdown
- DocUtils - An open-source text processing system for processing plaintext documentation into useful formats, such as HTML, LaTeX, man-pages, open-document, or XML
    - reStructuredText - An easy-to-read, what-you-see-is-what-you-get plaintext markup syntax and parser system
- Asciidoc - A lightweight markup language for writing notes, documentation, articles, books, ebooks, slideshows, web pages, man pages and blogs
    - Asciidoctor - A fast, open source text processor and publishing toolchain for converting AsciiDoc content to HTML5, DocBook 5 (or 4.5) and other formats
- Org Mode - An authoring tool and a TODO lists manager for GNU Emacs
    - nvim-orgmode - An Orgmode clone for Neovim written in Lua
- Wikitext - The markup language that consists of the syntax and keywords used by the MediaWiki software to format a page

- Style Guides
    - Microsoft Writing Style Guide - A guide for writers creating a variety of content types, including apps and websites
    - Google documentation style guide - The editorial guidelines for writing clear and consistent technical documentation for an audience of software developers and other technical practitioners
    - Red Hat documentation style guide - The guide that provides style guidelines for Red

Hat product and cross-product solution documentation

- Microsoft Terminology - A collection of rules that define language and style conventions for specific languages
- List of English words - A text file containing over 466k English words

- Prose Linters
  - vale - A linter for natural language/prose
  - retext - An extensible natural language processor
  - alex - A tool that helps you find gender favoring, polarizing, race related, religion inconsiderate, or other unequal phrasing in text
  - write-good - A naive linter for English prose
  - textlint - The pluggable linting tool for text and markdown

Documentation Tooling

- Typesetting Systems
  - Typst - A new markup-based typesetting system that is designed to be as powerful as LaTeX while being much easier to learn and use
  - Troff/Groff - A typesetting system that reads plain text mixed with formatting commands and produces formatted output
  - LaTeX - A high-quality typesetting system; it includes features designed for the production of technical and scientific documentation
    - TexLive - A cross-platform, free software distribution for the TeX typesetting system
    - PGF/TikZ - A TeX macro package for generating graphics
  - KaTeX - The fastest math typesetting library for the web
    - sphinxcontrib-katex - A Sphinx extension which allows you to use KaTeX to render math in your Sphinx documentation
- Validation & Maintenance
  - lychee - A fast, async link checker written in Rust
- Converters
  - Pandoc - A universal document converter
    - Eisvogel - A pandoc LaTeX template to convert markdown files to PDF or LaTeX

Interpersonal & Team Leadership

:::note[Relevant DSS-P Skills]

- 5. Personal Skill > 5.1 Human Skill > Leadership
- 5. Personal Skill > 5.1 Human Skill > Collaboration

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==== Team Dynamics & Communication

- Team Dynamics
  - Team building - A collective term for various types of activities used to enhance social relations and define roles within teams, often involving collaborative tasks
    - Tuckman’s stages of group development - A model of group development that was first proposed by Bruce Tuckman in 1965
  - Group dynamics - A system of behaviors and psychological processes occurring within or between social groups
  - Research & Models
    - Google Rework: Understand team effectiveness - A research initiative identifying key dynamics like psychological safety, dependability, structure and clarity, meaning, and impact as crucial for successful group collaboration
    - GRPI Model - A foundational framework for designing and diagnosing team effectiveness, organizing the building blocks of a high-performing team into four layers: Goals, Roles, Processes, and Interpersonal Relationships
- Interpersonal Communication Techniques
  - Storytelling - The social and cultural activity of sharing stories, sometimes with improvisation, theatrics or embellishment
  - Facilitation - The act of designing and running a successful meeting or workshop
  - Active listening - The practice of preparing to listen, observing what verbal and non-verbal messages are being sent, and then providing appropriate feedback for the sake of showing attentiveness to the message being presented
  - Negotiation - A dialogue between two or more parties to resolve points of difference, gain an advantage for an individual or collective, or craft outcomes to satisfy various interests
- Corporate Principles & Values
  - Amazon’s Leadership Principles - The set of core tenets Amazonians use daily to guide their discussions, decisions, and actions
  - GitLab Values - A set of guiding principles that define the company’s culture and how its team members operate
- Professional Manifestos
  - Manifesto for Software Craftsmanship - A declaration emphasizing the importance of well-crafted software, continuous value addition, professional community, and productive partnerships in software development
- Feedback Models
  - DESC feedback model - A communication tool for providing constructive feedback by describing the behavior, expressing the impact, specifying the desired change, and explaining the consequences

Organizational Behavior

- Stakeholder management - The process of identifying individuals or groups that are affected by a project or business venture, understanding their interests and concerns, and managing their expectations and influence
- Contingency theory - A theory that claims there is no single best way to organize a corporation, lead a company, or make decisions, asserting that the optimal course of action depends on internal and external situations
- Expectancy theory - A theory that proposes an individual's behavior is motivated by the expected results of their actions, with the desirability of the outcome determining the selection of a specific behavior
- Intrinsic motivation - A type of motivation that arises from internal factors, such as enjoyment, curiosity, or a sense of fulfillment, where individuals engage in an activity for its own sake
- Management 3.0 - An ever-evolving mindset and a collection of games, tools, and practices designed to help any worker manage the organization and improve work systems
- PM Theory of Leadership - A leadership theory that classifies leaders into two categories: performance-oriented and maintenance-oriented
- Theory X and Theory Y - The theories of human work motivation and management developed by Douglas McGregor
- Two-factor theory - A theory developed by psychologist Frederick Herzberg, it posits that job satisfaction and dissatisfaction are influenced by separate sets of factors, known as motivators and hygiene factors, which act independently of each other

Leadership Styles

- Servant leadership - A leadership philosophy where the primary aim of the individual in charge is to prioritize the needs of their team members, fostering their development and performance, rather than focusing on personal gain or traditional hierarchical authority
- Shared leadership - A leadership style that broadly distributes responsibility, allowing individuals within a team or organization to lead each other
- Situational leadership - A leadership model where effective leaders adapt their style to each situation, recognizing that no single approach is universally appropriate
- Transformational leadership - A leadership style in which leaders encourage, inspire, and motivate employees to innovate and create change that will help grow and shape the future success of the company

Individual Psychology & Performance

:::note[Relevant DSS-P Skills]

- 5. Personal Skill > 5.2 Conceptual Skill > Adaptability

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==== Personal Performance

- Mental Health
  - Mindfulness - The basic human ability to be fully present, aware of where we are and what we're doing, and not overly reactive or overwhelmed by what's going on around us
    - Zen - A school of Mahayana Buddhism that originated in China during the Tang dynasty
  - Flow - The mental state in which a person performing some activity is fully immersed in a feeling of energized focus, full involvement, and enjoyment in the process of the activity
  - Defence mechanism - Unconscious psychological processes that protect the self from anxiety-producing thoughts and feelings related to internal conflicts and external stressors
  - Psychological resilience - The ability to cope mentally and emotionally with a crisis, or to return to pre-crisis status quickly
  - Occupational burnout - A work-related phenomenon resulting from chronic workplace stress that has not been successfully managed
- Cognitive Performance / Decision Making
  - Maslow's Hierarchy of Needs - A conceptualisation of the needs (or goals) that motivate human behavior
  - Cognitive bias - A systematic pattern of deviation from norm or rationality in judgment
  - Default mode network - A large-scale brain network; known for being active when a person is not focused on the outside world and the brain is at wakeful rest
  - Situation awareness - The understanding of an environment, its elements, and how it changes with respect to time or other factors
    - 1: Perception of the elements in the environment.
    - 2: Comprehension or understanding of the situation.
    - 3: Projection of future status.
  - Vertical thinking - A problem-solving approach characterized by being selective, analytical, and sequential, often relying on rational assessment and external data
  - Lateral thinking - A manner of solving problems using an indirect and creative approach via reasoning that is not immediately obvious
- Related Philosophies
  - Three Virtues - The qualities of a great programmer: Laziness, Impatience, and Hubris
- Related Books
  - Thinking, Fast and Slow - A 2011 book by psychologist Daniel Kahneman

Social Performance

- Social Psychology
  - Psychological safety - The belief that one will not be punished or humiliated for speaking up with ideas, questions, concerns, or mistakes
  - Trust - The belief that another person will do what is expected
  - Collective intelligence - The shared or group intelligence that emerges from the collaboration, collective efforts, and competition of many individuals and appears in consensus decision making
  - Groupthink - A psychological phenomenon that occurs within a group of people in which the desire for harmony or conformity in the group results in an irrational or dysfunctional decision-making outcome
  - Bystander effect - A social psychological theory that states that individuals are less likely to offer help to a victim when there are other people present
  - Dunbar's number - A suggested cognitive limit to the number of people with whom one can maintain stable social relationships
- Illustrative Concepts
  - Broken windows theory - A criminological theory that states that visible signs of crime, anti-social behavior, and civil disorder create an urban environment that encourages further crime and disorder, including serious crimes
  - Stone soup story - A European folk story in which hungry strangers convince the people of a town to each share a small amount of their food in order to make a meal
  - Boiling frog apologue - An apologue describing a frog being slowly boiled alive

Timeline - 1930-79

1930s

Lambda calculus is a formal system in mathematical logic for expressing computation based on function abstraction and application using variable binding and substitution, introduced by mathematician Alonzo Church in the 1930s as part of an investigation into the foundations of mathematics, though the original system was shown to be logically inconsistent in 1935.

A Turing machine is a mathematical model of computation describing an abstract machine that manipulates symbols on a strip of tape according to a table of rules, invented by Alan Turing in 1936 and named by his doctoral advisor Alonzo Church in a later review.

1940s

In computer programming, assembly language is any low-level programming language with a very strong correspondence between the instructions in the language and the architecture's machine code instructions, with the first assembly code used to represent machine code instructions appearing in Kathleen and Andrew Donald Booth's 1947 work.

1950s

The Turing test, originally called the imitation game by Alan Turing in 1950, is a test of a machine’s ability to exhibit intelligent behavior equivalent to, or indistinguishable from, that of a human.

Regular expressions originated in 1951, when mathematician Stephen Cole Kleene described regular languages using his mathematical notation called regular events.

The caesium atomic clock was first built in 1955 by Louis Essen at the National Physical Laboratory (NPL) in the UK, providing a form of timekeeping far more stable and precise than astronomical observations, and laying the foundation for the modern definition of the SI second and Coordinated Universal Time (UTC).

Lisp is a family of programming languages with a long history and a distinctive, fully parenthesized prefix notation, originally specified in 1958 when John McCarthy developed it at the Massachusetts Institute of Technology (MIT), making it the second-oldest high-level programming language still in common use.

ALGOL (short for "Algorithmic Language") is a family of imperative computer programming languages originally developed in 1958 that heavily influenced many other languages and became the standard method for algorithm description.

In machine learning, the perceptron (or McCulloch-Pitts neuron) is an algorithm for supervised learning of binary classifiers, with the first implementation being a machine built in 1958 at the Cornell Aeronautical Laboratory by Frank Rosenblatt.

The term machine learning was coined in 1959 by Arthur Samuel, an IBM employee and pioneer in the field of computer gaming and artificial intelligence. The synonym self-teaching computers was also used in this time period.

1960s

Passwords have been used with computers since the earliest days of computing. The Compatible Time-Sharing System (CTSS), an operating system introduced at MIT in 1961, was the first computer system to implement password login.

In May 1961, IBM engineer Bob Bemer submitted a proposal to the American Standards Association’s (ASA) X3.2 subcommittee, initiating formal standardization work on ASCII (American Standard Code for Information Interchange). Bemer, who also invented the escape sequence, later became known as "the father of ASCII."

Simula is the name of two simulation programming languages developed in the 1960s at the Norwegian Computing Center in Oslo by Ole-Johan Dahl and Kristen Nygaard, with Simula 67 introducing objects, classes, inheritance, subclasses, virtual procedures, coroutines, discrete event simulation, and garbage collection, first appearing in 1962.

In machine learning, backpropagation is a gradient estimation method used to train neural network models. The term "back-propagating error correction" was introduced in 1962 by Frank Rosenblatt, but he did not know how to implement it, even though Henry J. Kelley had

a continuous precursor of backpropagation already in 1960 in the context of control theory.

The first edition of ASCII (ASA X3.4-1963) was published in 1963, coinciding with the introduction of the Teletype Model 33. It was first used commercially as a seven-bit teleprinter code for AT&T's TWX (TeletypeWriter eXchange) network.

In 1964, for the Multics operating system, Louis Pouzin conceived the idea of "using commands somehow like a programming language," and coined the term shell to describe it.

Conway's law is an adage that states organizations design systems that mirror their own communication structure. It is named after the computer programmer Melvin Conway, who introduced the idea in 1967.

The PIN originated with the introduction of the automated teller machine (ATM) in 1967, as an efficient way for banks to dispense cash to their customers. The first ATM system was that of Barclays in London, in 1967; it accepted cheques with machine-readable encoding, rather than cards, and matched the PIN to the cheque.

Pseudoterminals appeared as early as 1967 in the DEC PDP-6 Timesharing Monitor, where they were primarily used to implement batch processing.

ed is a line editor for Unix and Unix-like operating systems, developed by Ken Thompson in August 1969 on a PDP-7 at AT&T Bell Labs as one of the first three key elements of the Unix operating system alongside the assembler and shell.

Hoare logic is a formal system with a set of logical rules for reasoning rigorously about the correctness of computer programs. It was proposed in 1969 by the British computer scientist and logician Tony Hoare, and subsequently refined by Hoare and other researchers.

Unix (trademarked as UNIX) is a family of multitasking, multiuser computer operating systems that derive from the original AT&T Unix, first released in 1969.

The Advanced Research Projects Agency Network (ARPANET) was the first wide-area packet-switched network with distributed control and one of the first networks to implement the TCP/IP protocol suite, both of which became the technical foundation of the Internet, established in 1969.

In computing, "server" dates at least to RFC 5 (1969), one of the earliest documents describing ARPANET (the predecessor of Internet), and is contrasted with "user", distinguishing two types of host: "server-host" and "user-host".

Telnet (short for "teletype network") is a client/server application protocol that provides access to virtual terminals of remote systems on local area networks or the Internet, developed as secret technology beginning in 1969 with RFC 15.

1970-74

The term "relational database" was first defined by E. F. Codd at IBM in 1970. Codd introduced the term in his research paper "A Relational Model of Data for Large Shared Data Banks".

The File Transfer Protocol (FTP) is a standard communication protocol used for the transfer of computer files from a server to a client on a computer network, introduced on April 16, 1971.

mail is a command-line email client for Unix and Unix-like operating systems, first released on November 3, 1971.

roff is a typesetting markup language and the first Unix text-formatting computer program, serving as a predecessor of the nroff and troff document processing systems, first released on November 3, 1971.

In 1971 the first ARPANET network mail was sent, introducing the now-familiar address syntax with the '@' symbol designating the user’s system address. Over a series of RFCs, conventions were refined for sending mail messages over the File Transfer Protocol.

yacc (Yet Another Compiler Compiler) is a parser generator for context-free grammars that produces C code for LALR parsers. It was first developed by Stephen C. Johnson at Bell Labs in 1971, inspired by Donald Knuth’s work on LR parsing; the self-deprecating name reflected the existence of other compiler-compilers at Bell Labs from the Multics project. By 1973 it had reached a form recognizably similar to its C implementation, though early versions were extremely slow and Johnson rewrote it over a dozen times to improve performance by a factor of roughly 10,000.

ML (Meta Language) was released in 1972 by Robin Milner at Stanford (and later Cambridge) as the meta-language for the LCF (Logic for Computable Functions) proof assistant, providing the foundational type system for OCaml.

C is a middle-level, general-purpose computer programming language created by Dennis Ritchie between 1972 and 1973 at Bell Labs to construct utilities running on Unix, remaining very widely used and influential due to its design that cleanly reflects the capabilities of targeted CPUs.

Smalltalk is an object-oriented, dynamically typed reflective programming language designed for educational use as the product of research led by Alan Kay at Xerox Palo Alto Research Center (PARC), with the first system (Smalltalk-72) running on a Xerox Alto and designed to support Kay’s new object-oriented programming paradigm.

In June 1972, five IBM engineers from the AI department founded SAP (Systemanalyse und Programmentwicklung, "System Analysis and Program Development") as a private partnership under German Civil Code, launching its first commercial product, the RF financial accounting system, in 1973.

In 1973, Version 4 Unix was rewritten in the higher-level language C, contrary to the general notion at the time that an operating system’s complexity and sophistication required it to be written in assembly language.

sed ("stream editor") is a Unix utility that parses and transforms text using a simple, compact programming language, developed from 1973 to 1974 by Lee E. McMahon of Bell Labs.

TCP provides reliable, ordered, and error-checked delivery of a stream of octets (bytes)

between applications running on hosts communicating via an IP network. In May 1974, Vint Cerf and Bob Kahn described an internetworking protocol for sharing resources using packet switching among network nodes, with the specification of the resulting protocol (TCP/IP) written by Vint Cerf, Yogen Dalal, and Carl Sunshine and published in December 1974.

Structured Query Language (SQL) is a domain-specific language used in programming and designed for managing data held in a relational database management system (RDBMS) or for stream processing in a relational data stream management system (RDSMS), first appearing in 1974.

1975-79

The Data Encryption Standard is a symmetric-key algorithm for the encryption of digital data whose short key length of 56 bits makes it too insecure for modern applications, yet it has been highly influential in the advancement of cryptography. The origins of DES date to 1972 when a National Bureau of Standards study of US government computer security identified a need for a government-wide standard for encrypting unclassified, sensitive information. On March 17, 1975, the proposed DES was published in the Federal Register, with public comments requested and two open workshops held in the following year to discuss the proposed standard.

The Mythical Man-Month: Essays on Software Engineering by Fred Brooks was first published in 1975.

The cron command-line utility is a job scheduler on Unix-like operating systems used to schedule jobs (commands or shell scripts), also known as cron jobs, to run periodically at fixed times, dates, or intervals, first released in May 1975.

lex is a lexical analyzer generator that reads a specification of tokens and produces C code for a lexer. It was developed at Bell Labs by Mike Lesk and Eric Schmidt and first documented in October 1975 as Computing Science Technical Report #39. The same year, Stephen C. Johnson published the formal yacc paper; among the first languages implemented with yacc were AWK, C++, eqn, and Pic.

Make is a build automation tool that automatically builds executable programs and libraries from source code by reading files called Makefiles that specify how to derive the target program, first appearing in April 1976.

vi is a screen-oriented text editor originally created for the Unix operating system, with the original code written by Bill Joy in 1976 as the visual mode for a line editor called ex that Joy had written with Chuck Haley.

Diffie–Hellman key exchange is a mathematical method of securely exchanging cryptographic keys over a public channel, published in 1976 by Diffie and Hellman as the earliest publicly known work proposing the idea of a private key and a corresponding public key.

AWK is a domain-specific language designed for text processing and typically used as a data extraction and reporting tool, initially developed in 1977 by Alfred Aho (author of egrep),

Peter J. Weinberger (who worked on tiny relational databases), and Brian Kernighan.

RSA is a public-key cryptosystem widely used for secure data transmission, with the acronym "RSA" coming from the surnames of Ron Rivest, Adi Shamir and Leonard Adleman, who publicly described the algorithm in 1977.

The Data Encryption Standard was standardized in January 1977, despite its short 56-bit key length making it too insecure for modern applications, yet it has been highly influential in the advancement of cryptography.

Bill Joy’s ex 1.1 was released as part of the first Berkeley Software Distribution (BSD) Unix release in March 1978, with many of the ideas in this visual mode taken from Bravo — the bimodal text editor developed at Xerox PARC for the Alto.

In 1978, Brian Kernighan and Dennis Ritchie published the first edition of The C Programming Language. This book, known to C programmers as K&R, served for many years as an informal specification of the language. The version of C that it describes is commonly referred to as "K&R C".

TeX is a typesetting system designed and written by Donald Knuth and first released in 1978. The first version of TeX, called TeX78, was written in the SAIL programming language to run on a PDP-10 under Stanford’s WAITS operating system.

Taiichi Ohno published his seminal book, "Toyota Production System: Beyond Large-Scale Production," in 1978, formalizing the philosophy for a global audience.

The problem of obtaining Byzantine consensus was conceived and formalized by Robert Shostak, who dubbed it the interactive consistency problem. This work was done in 1978 in the context of the NASA-sponsored SIFT project in the Computer Science Lab at SRI International.

Model-view-controller (MVC) is a software design pattern commonly used for developing user interfaces that divides the related program logic into three interconnected elements. Trygve Reenskaug created MVC while working on Smalltalk-79 as a visiting scientist at the Xerox Palo Alto Research Center (PARC) in the late 1970s.

The Bourne shell, sh, was a new Unix shell developed by Stephen Bourne at Bell Labs and distributed as the shell for UNIX Version 7 in 1979.

A chroot on Unix and Unix-like operating systems is an operation that changes the apparent root directory for the current running process and its children. The chroot system call was introduced during development of Version 7 Unix in 1979.

Both lex and yacc became standard tools in the Unix toolchain with the release of Version 7 Unix in 1979, establishing them as foundational components for compiler and language development on Unix systems.

Oracle Database (commonly referred to as Oracle DBMS, Oracle Autonomous Database, or simply Oracle) is a proprietary multi-model database management system produced and marketed by Oracle Corporation, first released in 1979.

Jef Raskin, an Apple employee, initiated the Macintosh project in 1979, envisioning an affordable, easy-to-use computer for the masses. He named the project after his favorite apple variety, the McIntosh.

1980-84

Smalltalk-80 was the first language variant made available outside of PARC, first as Smalltalk-80 Version 1, given to a small number of firms and universities.

Steve Jobs took over the Macintosh project in 1981 after being removed from the Lisa team, redirecting the design toward a Xerox PARC-inspired graphical user interface while retaining Jef Raskin’s vision of producing computers by the millions.

The Berkeley r-commands are a suite of computer programs designed to enable users of one Unix system to log in or issue commands to another Unix computer via TCP/IP network, first released in June 1981.

IPv4 is described in RFC 791 (1981).

In March 1982, the US Department of Defense declared TCP/IP as the standard for all military computer networking.

The Mythical Man-Month was reprinted with corrections in 1982

Microsoft Multiplan, an early spreadsheet program developed by Microsoft, was released in August 1982.

Revision Control System (RCS) is an early implementation of a version control system (VCS), a set of UNIX commands that allow multiple users to develop and maintain program code or documents. RCS was first released in 1982 by Walter F. Tichy at Purdue University and is currently maintained by the GNU Project.

John Warnock and Charles Geschke left Xerox PARC and founded Adobe Systems in December 1982. They began developing PostScript, a page description language drawing on Warnock’s earlier Interpress research at Xerox, with the goal of providing a device-independent way to describe printed pages.

TeX82, a new version of TeX rewritten from scratch, was published in 1982. Among other changes, the original hyphenation algorithm was replaced by a new algorithm written by Frank Liang.

The migration of the ARPANET from NCP to TCP/IP was officially completed on flag day January 1, 1983, when the new protocols were permanently activated.

Lotus 1-2-3 was officially released for the IBM PC on January 26, 1983, quickly becoming the platform’s "killer app" by integrating spreadsheet, graphing, and data management capabilities into a single, high-performance program written in x86 assembly.

The r-commands (including rlogin, rsh, and rcp) were fully incorporated into 4.2BSD in August 1983, a release that provided the mature interprocess communication (IPC)

primitives that enabled them to become the de facto standards for Unix networking throughout the 1980s.

Development of the GNU operating system was initiated by Richard Stallman while he worked at MIT Artificial Intelligence Laboratory. It was called the GNU Project, and was publicly announced on September 27, 1983.

The Internet Engineering Task Force published the DNS original specifications in RFC 882 and RFC 883 in November 1983.

The Simple Mail Transfer Protocol (SMTP) protocol was implemented on the ARPANET in 1983.

The modern Unix pseudoterminal interface originated in 1983 during the development of Eighth Edition Unix and was widely popularized following its inclusion in the 4.2BSD (Berkeley Software Distribution) release.

In the spring of 1983, Steve Jobs visited Adobe and was dazzled by PostScript's potential for the Macintosh. Apple and Adobe signed a PostScript licensing deal in December 1983, with Apple investing in Adobe and agreeing to use PostScript in its upcoming laser printer.

The original Macintosh 128K was introduced by Steve Jobs on January 24, 1984, at a price of US$2,495. It was the first commercially successful personal computer to feature a mouse-driven graphical user interface, using a Motorola 68000 processor and a 9-inch monochrome display.

In 1984, four UC Berkeley students, Douglas Terry, Mark Painter, David Riggle, and Songnian Zhou, wrote the first Unix name server implementation for the Berkeley Internet Name Domain, commonly referred to as BIND.

X/Open group was a consortium founded by several European UNIX systems manufacturers in 1984 to identify and promote open standards in the field of information technology.

Eliyahu M. Goldratt introduced the Theory of Constraints to a wide audience in his business novel, The Goal, in 1984.

TeX has been the official typesetting package for the GNU operating system since 1984.

Timeline - 1980-99

1985

Apple and Adobe announced the LaserWriter on January 23, 1985 — the first printer to ship with PostScript — at Apple's annual shareholder meeting. Aldus simultaneously announced PageMaker, triggering the desktop publishing revolution.

GNU Emacs is a free software text editor created by GNU Project founder Richard Stallman based on the Emacs editor developed for Unix operating systems, written in C and providing Emacs Lisp (also implemented in C) as an extension language, with version 13 as the first public release on March 20, 1985.

The GNU Manifesto is a call-to-action by Richard Stallman encouraging participation and support of the GNU Project’s goal in developing the GNU free computer operating system. It was published in March 1985.

Aldus PageMaker 1.0 was released in July 1985 for the Macintosh with native PostScript support, becoming the first widely adopted desktop publishing application and cementing PostScript as the standard page description language for professional printing. PageMaker won a Codie Award for Best New Use of a Computer in 1986.

Microsoft Excel was first released for the Macintosh on September 30, 1985, and was the first spreadsheet to allow the user to define the appearance of spreadsheets.

Lotus 1-2-3 Release 2.0 was launched in September 1985, introducing support for macros, add-ins, and expanded memory (EMS), which solidified its dominance in the corporate spreadsheet market.

Microsoft Windows was first announced by Bill Gates on November 10, 1983, as a graphical user interface for MS-DOS, and Windows 1.0 was officially released on November 20, 1985.

LaTeX was created in the early 1980s by Leslie Lamport while working at Stanford Research Institute (SRI), originally written to fulfill his own need for TeX macros but designed with the intent to be made into a general package usable by others, with versions released in 1984 and 1985.

The Free Software Foundation was founded in 1985 as a non-profit corporation supporting free software development.

C is a high-level general-purpose programming language created by Danish computer scientist Bjarne Stroustrup as an extension of the C programming language (or "C with Classes"), first appearing in 1985 and initially standardized in 1998 as ISO/IEC 14882:1998, which was subsequently amended by the C03, C11, C14, and C++17 standards.

GNU Bison, a free yacc-compatible parser generator, was originally written by Robert Corbett in 1985. Richard Stallman subsequently made it fully yacc-compatible as part of the GNU Project, with Wilfred Hansen of Carnegie Mellon University adding multi-character string literals and other features.

1986

Hirotaka Takeuchi and Ikujiro Nonaka introduced the term "scrum" in the context of product development in their Harvard Business Review article "The New New Product Development Game" in January–February 1986.

GDB is free software released under the GNU General Public License, first written by Richard Stallman in 1986 as part of his GNU system after GNU Emacs reached a "reasonably stable" state.

The Standard Generalized Markup Language (SGML; ISO 8879:1986) is a standard for defining generalized markup languages for documents.

Dick Grune at Vrije Universiteit Amsterdam developed an early form of CVS in July 1986 as a set of shell scripts wrapping RCS, to allow multiple developers to work on the same files concurrently.

In machine learning, backpropagation is a widely used algorithm for training feedforward artificial neural networks or other parameterized networks with differentiable nodes, with David E. Rumelhart et al. publishing an experimental analysis in 1986 that contributed to its popularization and helped initiate an active period of research in multilayer perceptrons.

The term Deep Learning was introduced to the machine learning community by Rina Dechter in 1986.

gnuplot is a command-line and GUI program that can generate two- and three-dimensional plots of functions, data, and data fits across all major computers and operating systems (Linux, Unix, Microsoft Windows, macOS, FreeDOS, and many others), first released in 1986.

The POSTGRES project officially launched at UC Berkeley in 1986 under the leadership of Michael Stonebraker, aiming to solve the limitations of the relational model by introducing object-relational concepts.

1987

The Macintosh SE and Macintosh II were both introduced at the AppleWorld conference in Los Angeles on March 2, 1987. The Macintosh II was Apple’s first modular and color-capable Macintosh, breaking from the all-in-one design of earlier models.

The GNU Compiler Collection (GCC) is an optimizing compiler produced by the GNU Project supporting various programming languages, hardware architectures, and operating systems. Originally named the GNU C Compiler when first released by Richard Stallman on March 22, 1987 (available via FTP from MIT) because it only supported the C programming language, GCC has since evolved to support many more languages.

flex (Fast Lexical Analyzer Generator) is a free reimplementation of lex that produces faster and more efficient C code for scanners. It was written by Vern Paxson at UC Berkeley around 1987 with inspiration from Van Jacobson, removing the proprietary licensing restrictions that had limited the original AT&T lex’s adoption outside commercial Unix environments.

Peopleware: Productive Projects and Teams by Tom DeMarco and Tim Lister was first published in 1987.

Windows 2.0, released on December 9, 1987, introduced overlapping windows, desktop icons, and keyboard shortcuts, significantly improving the user experience over the previous version.

Perl is a family of high-level, general-purpose, interpreted, dynamic programming languages developed by Larry Wall in 1987 as a general-purpose Unix scripting language to make report processing easier, first appearing on December 18, 1987.

The first Windows version of Excel was released on November 19, 1987, numbered as version 2.0 to be in line with the Macintosh version, and included a run-time version of Windows.

In 1987, a committee of researchers convened to create a standardized, purely functional language, which would come to be known as Haskell.

Self is an object-oriented programming language based on the concept of prototypes, designed mostly by David Ungar and Randall Smith while working at Xerox PARC in 1986. It began as a Smalltalk dialect with dynamic typing, just-in-time compilation (JIT), and a prototype-based approach to objects, first appearing in 1987.

The first implementation of Caml (Categorical Abstract Machine Language) was created by Ascánder Suárez at INRIA in 1987 based on the Categorical Abstract Machine compiling method.

SQL was adopted as a standard by the ANSI in 1986 as SQL-86 and the ISO in 1987.

1988

Wolfram Mathematica is a software system with built-in libraries for technical computing including machine learning, statistics, symbolic computation, data manipulation, network analysis, time series analysis, NLP, optimization, plotting, algorithm implementation, user interface creation, and interfacing with programs in other languages, first released on June 23, 1988.

Joe Becker of Xerox published a draft proposal in August 1988 for an international/multilingual text character encoding system tentatively called "Unicode," outlined in a document entitled *Unicode 88*, proposing a 16-bit character scheme developed with Lee Collins and Mark Davis of Apple.

Internet Relay Chat (IRC), a text-based chat system, was created by Jarkko Oikarinen in August 1988 at the University of Oulu, Finland, originally intended to replace a program called MUT (MultiUser Talk) on a BBS called OuluBox.

The Morris worm or Internet worm of November 2, 1988, is one of the oldest computer worms distributed via the Internet, and the first to gain significant mainstream media attention.

X.509 is an International Telecommunication Union (ITU) standard defining the format of public key certificates, first published on November 25, 1988.

GNU Make (short gmake) is the standard implementation of Make for Linux and macOS, providing several extensions over the original Make such as conditionals, built-in functions to eliminate the need for shell scripting in makefile rules, and the ability to manipulate variables, first released in 1988.

GNU Octave was conceived in 1988 by John W. Eaton at the University of Texas at Austin as a high-level language for numerical computations, originally intended as a companion for a chemical reactor design course.

AWK was significantly revised and expanded in 1985-88, resulting in the GNU AWK implementation written by Paul Rubin, Jay Fenlason, and Richard Stallman, released in 1988.

The Open Software Foundation (OSF) was a not-for-profit industry consortium formed in 1988 to create an open standard for Unix operating system implementations.

The Portable Operating System Interface (POSIX) is a family of standards specified by the IEEE Computer Society for maintaining compatibility between operating systems, defining both system- and user-level application programming interfaces (APIs), developed starting in 1988.

The concept of data warehousing dates back to the late 1980s when IBM researchers Barry Devlin and Paul Murphy developed the "business data warehouse" and published the article "An architecture for a business and information system" in 1988 introducing the term to the broader audience.

1989

Kerberos is a computer-network authentication protocol that works using tickets to allow nodes communicating over non-secure networks to prove their identity to one another securely, developed by the Massachusetts Institute of Technology (MIT) in 1988 to protect network services provided by Project Athena. Kerberos version 4, the first public version, was released on January 24, 1989.

Microsoft SQL Server is a proprietary relational database management system developed by Microsoft that functions as a database server with the primary purpose of storing and retrieving data as requested by other software applications, with initial release on April 24, 1989.

Brian Berliner redesigned and rewrote CVS in C in April 1989, vastly improving performance and reliability over Grune’s original shell script implementation.

Bash is a Unix shell and command language written by Brian Fox for the GNU Project as a free software replacement for the Bourne shell, first released on June 8, 1989, and has been used as the default login shell for most Linux distributions.

Lotus 1-2-3 Release 3.0 was released in June 1989 as a major rewrite in the C language, introducing "3D spreadsheets" with multiple worksheets in a single file, though it required newer 80286-based hardware to run.

POSTGRES Version 1 was released to a small group of external users in June 1989, marking the first public implementation of the extensible database system developed at Berkeley.

NeXTSTEP 1.0, the object-oriented, multitasking operating system developed by NeXT Computer founded by Steve Jobs after leaving Apple in 1985, was released on September 18, 1989. Built on the Mach kernel and BSD, it would later become the foundation for Mac OS X and modern macOS.

The Hypertext Transfer Protocol (HTTP) is an application layer protocol in the Internet protocol suite model for distributed, collaborative, hypermedia information systems. Development of HTTP was initiated by Tim Berners-Lee at CERN in 1989 and summarized in a simple document describing the behavior of a client and a server using the first HTTP protocol version that was named 0.9.

1990

The book "The Machine That Changed the World" was published in 1990, coining the term "Lean Manufacturing" to describe the Toyota Production System methodology to the West.

Windows 3.0, launched on May 22, 1990, became the first version of Windows to achieve widespread commercial success, featuring a completely redesigned user interface and improved memory management for 386 processors.

Microsoft released OLE 1.0 (Object Linking and Embedding) in 1990, introducing the first document-linking and embedding technology for Windows that allowed software components to interact.

groff (also called GNU troff) is a typesetting system that creates formatted output when given plain text mixed with formatting commands, with version 0.3.1 first released in June 1990.

The first version of the language definition, Haskell 1.0, was published in 1990.

CVS (Concurrent Versions System) version 1.0 was publicly released on November 19, 1990, becoming one of the dominant version control systems throughout the 1990s.

flex was publicly released in 1990 under a BSD-style license by the Regents of the University of California, making it the first freely available replacement for the proprietary AT&T lex and enabling widespread adoption across open-source Unix projects.

CERN httpd (later also known as W3C httpd) is an early, now discontinued, web server (HTTP) daemon originally developed at CERN from 1990 onwards by Tim Berners-Lee, Ari Luotonen and Henrik Frystyk Nielsen. Implemented in C, it was the first web server software, with its initial release on December 24, 1990.

In 1990, Tim Berners-Lee’s proposals for hypertext implicitly introduced the idea of a URL as a short string representing a resource that is the target of a hyperlink.

1991

The Unicode Consortium was incorporated in California on January 3, 1991, as a non-profit organization to develop, extend, and promote the use of the Unicode Standard.

The first web browser, WorldWideWeb, was developed in 1990 by Tim Berners-Lee for the NeXT Computer and introduced to his colleagues at CERN in March 1991.

The Linux kernel is a free and open-source, monolithic, modular, multitasking, Unix-like operating system kernel. In April 1991, Linus Torvalds, a 21-year-old computer science student at the University of Helsinki, started working on a simple operating system inspired

by UNIX for his i386-based PC, beginning with a task switcher in Intel 80386 assembly language and a terminal driver.

Linus Torvalds announced his project on the `comp.os.minix` newsgroup on August 25, 1991, famously describing it as "just a hobby, won't be big and professional like gnu."

On 17 September 1991, Torvalds released version 0.01 of the Linux kernel on the FUNET FTP server. It was not yet executable and required MINIX for compilation.

On 5 October 1991, Torvalds announced the first "official" version of Linux, version 0.02. At this point, the kernel was capable of running the Bash shell and GCC.

Unicode 1.0 was published in October 1991, encoding 7,161 characters from 24 scripts in a unified 16-bit character set intended to encompass all modern writing systems.

Vim (a contraction of Vi IMproved) is a free and open-source, screen-based text editor program and an improved clone of Bill Joy's vi. Vim's author, Bram Moolenaar, derived Vim from a port of the Stevie editor for Amiga and released the initial version to the public on November 2, 1991.

Python is a high-level, interpreted, general-purpose programming language with design philosophy emphasizing code readability through significant indentation. Guido van Rossum began working on Python in the late 1980s as a successor to the ABC programming language and first released it in 1991 as Python 0.9.0.

In 1991, the autoencoder was first proposed as a nonlinear generalization of principal components analysis (PCA) by Kramer.

Pretty Good Privacy (PGP) is an encryption program that provides cryptographic privacy and authentication for data communication. PGP is used for signing, encrypting, and decrypting texts, e-mails, files, directories, and whole disk partitions and to increase the security of e-mail communications. Phil Zimmermann developed PGP in 1991.

In 1991, the rlogin protocol was formally defined in RFC 1282, documenting the existing practice that had been widely adopted by the Unix community for over a decade.

1992

Windows 3.1, released on April 6, 1992, introduced TrueType fonts, the Windows Registry, and dropped support for Real Mode, marking a major step toward a more modern operating system architecture.

Linux 0.12 was released on February 1, 1992, under the GNU General Public License (GPL), marking a pivotal shift from its original restrictive license.

MD5 is one in a series of message digest algorithms designed by Professor Ronald Rivest of MIT. When analytic work indicated that MD5's predecessor MD4 was likely to be insecure, Rivest designed MD5 in 1991 as a secure replacement and first published it in April 1992.

UTF-8 was designed by Ken Thompson and Rob Pike on September 2, 1992, sketched on a

placemat in a New Jersey diner. They implemented it and updated Plan 9 from Bell Labs to use it throughout, creating a self-synchronizing, backward-compatible variable-length encoding for Unicode.

libwww (Library World Wide Web) is a modular client-side web API for Unix and Windows, and the reference implementation of the libwww API. In 1991 and 1992, Tim Berners-Lee and a student at CERN named Jean-François Groff rewrote various components of the original WorldWideWeb browser for the NeXTstep operating system in portable C code to demonstrate the potential of the World Wide Web, with version 1.0 initially released in November 1992.

In November 1992 the IETF "URI Working Group" met for the first time.

CTAN (an acronym for "Comprehensive TeX Archive Network") is the authoritative place where TeX related material and software can be found for download. Built in 1992 by Rainer Schöpf and Joachim Schrod in Germany, Sebastian Rahtz in the UK, and George Greenwade in the U.S., it was officially announced at the EuroTeX conference at Aston University in 1993. The WEB server itself is maintained by Gerd Neugebauer.

The term technical debt is a qualitative description of the cost to maintain a system that is attributable to choosing an expedient solution for its development. The term was coined by Ward Cunningham in 1992. After reading Metaphors We Live By, Ward devised this debt metaphor to explain to his boss the need to refactor the financial product they were working on.

The original Berkeley Packet Filter (BPF) was introduced in 1992 in a research paper by Steven McCanne and Van Jacobson. It provided a way to filter network packets in the kernel, minimizing data copying between the kernel and user space.

1993

NCSA Mosaic 0.5, the first alpha/beta version of the web browser developed at the National Center for Supercomputing Applications (NCSA), was announced by Marc Andreessen for the X Window System on January 23, 1993.

PDF (Portable Document Format) was publicly introduced by Adobe Systems in January 1993 at the Windows and OS/2 Conference. Adobe made the PDF 1.0 specification freely available and released Acrobat 1.0 as the first reader/writer, aiming to enable consistent document exchange across any platform.

The NetBSD source code repository was established on March 21, 1993. The project was founded by Chris Demetriou, Theo de Raadt, Adam Glass, and Charles Hannum as a more open and community-driven alternative to 386BSD.

NCSA Mosaic 1.0 for the X Window System was officially released on April 21, 1993. It was the first browser to display images inline with text using the `<img>` tag, rather than in a separate window, which was instrumental in popularizing the World Wide Web.

The name FreeBSD was officially chosen by David Greenman on June 19, 1993. The project began as an effort to maintain the "unofficial 386BSD patchkit" after 386BSD development

slowed earlier in the year.

R was started by professors Ross Ihaka and Robert Gentleman as a programming language to teach introductory statistics at the University of Auckland, first appearing in August 1993.

NCSA released the first versions of Mosaic for Microsoft Windows and Apple Macintosh in September 1993, making the web accessible to non-technical home users.

Debian, also known as Debian GNU/Linux, is a Linux distribution composed of free and open-source software, developed by the community-supported Debian Project. The first version of Debian (0.01) was released on September 15, 1993.

FreeBSD 1.0-RELEASE was published on November 1, 1993, based on 4.3BSD-Net/2 and 386BSD. This initial release provided a robust BSD-based operating system for the PC architecture.

NCSA Mosaic 2.0 for Unix was released on November 10, 1993. It introduced support for HTML forms, which enabled the creation of the first dynamic and interactive web pages.

The Component Object Model (COM) was officially introduced in 1993 as the underlying binary architecture for OLE 2.0, establishing a language-independent standard for software component interoperability.

In 1993, Microsoft introduced OLE Automation, which enabled applications such as Microsoft Excel to expose their functionality to external scripting languages like Visual Basic.

Microsoft released Excel 5.0 in 1993, which included Visual Basic for Applications (VBA), a programming language that added the ability to automate tasks and provide user-defined functions.

In 1993, Microsoft launched Windows NT 3.1, the first version of the "New Technology" (NT) line, which featured a robust 32-bit kernel designed for high-end workstations and servers, separate from the consumer-oriented DOS-based line.

CFEngine is an open-source configuration management system written by Mark Burgess that provides automated configuration and maintenance of large-scale computer systems. The CFEngine project began in 1993 as a way for author Mark Burgess to get his work done by automating the management of a small group of workstations in the Department of Theoretical Physics.

The HyperText Markup Language or HTML is the standard markup language for documents designed to be displayed in a web browser, with its initial release in 1993.

FutureWave Software (founded by Charlie Jackson, Jonathan Gay, and Michelle Alsip-Welsh) published SmartSketch in 1993, a vector drawing application for pen computers. This was the earliest precursor to what would become Adobe Flash.

Common Gateway Interface (CGI) is an interface specification that enables web servers to execute an external program, typically to process user requests. In 1993, the National Center for Supercomputing Applications (NCSA) team wrote the specification for calling

command line executables on the www-talk mailing list.

NCSA HTTPd is an early, now discontinued, web server originally developed at the NCSA at the University of Illinois at Urbana–Champaign by Robert McCool and others, first released in 1993 and among the earliest web servers developed.

1994

GNU Octave 1.0 was officially released on February 17, 1994, establishing itself as a robust tool for scientific computing and engineering within the GNU project.

Linux version 0.95 was the first to be capable of running the X Window System. Linux 1.0.0 was released on March 14, 1994, consisting of 176,250 lines of code. It was the first version suitable for use in production environments.

In June 1994, the IETF published Berners-Lee's first Request for Comments that acknowledged the existence of URLs and URNs.

The World Wide Web Consortium (W3C) is the main international standards organization for the World Wide Web, founded on October 1, 1994, and led by Tim Berners-Lee.

Perl 5.000 was released on October 17, 1994. It was a nearly complete rewrite of the interpreter, and it added many new features to the language, including objects, references, lexical (my) variables, and modules

Netscape Navigator was a proprietary web browser and the original browser of the Netscape line (versions 1 to 4.08, and 9.x), serving as the flagship product of Netscape Communications Corp and the dominant web browser in terms of usage share in the 1990s, with initial release on December 15, 1994.

The QR code system was invented in 1994, at the Denso Wave automotive products company, in Japan.

SUnit, the first unit testing framework, was created by Kent Beck for Smalltalk in 1994. It introduced the test fixture pattern — setUp, test methods, and tearDown — that underlies the entire xUnit family of frameworks.

1995

Transport Layer Security (TLS) is a cryptographic protocol designed to provide communications security over a computer network. Netscape developed the original SSL protocols, and Taher Elgamal, chief scientist at Netscape Communications from 1995 to 1998, has been described as the "father of SSL". SSL Version 2.0, after being released in February 1995 was quickly discovered to contain a number of security and usability flaws.

Java is a high-level, class-based, object-oriented programming language designed to have as few implementation dependencies as possible. Originally developed by James Gosling at Sun Microsystems, Java SE defines a range of general-purpose APIs and includes the Java Language Specification and the Java Virtual Machine Specification, first appearing on May

23, 1995.

Java Applets were introduced with Java 1.0a2 and the HotJava browser, publicly demonstrated at SunWorld on May 23, 1995. They allowed small Java programs to be embedded in web pages and executed inside a sandboxed JVM provided by a browser plugin (NPAPI), enabling interactive content on the web.

MySQL is an open-source relational database management system (RDBMS) available as free and open-source software under the terms of the GNU General Public License, and also available under a variety of proprietary licenses, with initial release on May 23, 1995.

PHP is a general-purpose scripting language geared toward web development, originally created by Danish-Canadian programmer Rasmus Lerdorf in 1994 and first appearing on June 8, 1995.

Windows 95, released on August 24, 1995, was a massive consumer release that introduced the iconic Start menu, the Taskbar, and Plug and Play technology, while moving the consumer line toward a 32-bit architecture.

Theo de Raadt created the OpenBSD CVS repository on October 18, 1995, marking the official start of the project as a fork of NetBSD. The project was established following disagreements between de Raadt and the NetBSD core team, with a new focus on proactive security and code correctness.

CPAN was conceived in 1993 and has been active online since October 1995, based on the CTAN model and beginning as a place to unify the structure of scattered Perl archives. On October 26, 1995, the Comprehensive Perl Archive Network (CPAN) was established as a repository for the Perl language and Perl modules.

Ruby is an interpreted, high-level, general-purpose programming language which supports multiple programming paradigms. The first public release of Ruby 0.95 was announced on Japanese domestic newsgroups on December 21, 1995.

In December 1995, Sun Microsystems and Netscape announced JavaScript in a press release. The first JavaScript engine was created by Brendan Eich in 1995 for the Netscape Navigator web browser. It was a rudimentary interpreter for the nascent language Eich invented.

The predecessor of NumPy, Numeric, was originally created by Jim Hugunin with contributions from several other developers, with initial release in 1995.

The Apache HTTP Server is a free and open-source cross-platform web server software, released under the terms of Apache License 2.0, developed and maintained by an open community of developers under the auspices of the Apache Software Foundation, with initial release in 1995.

SHA-1 (Secure Hash Algorithm 1) is a hash function which takes an input and produces a 160-bit (20-byte) hash value known as a message digest — typically rendered as 40 hexadecimal digits. Designed by the United States National Security Agency, it is a U.S. Federal Information Processing Standard first published in 1995.

SSH was designed as a replacement for Telnet and for unsecured remote shell protocols such as the Berkeley rsh and the related rlogin and rexec protocols. In 1995, Tatu Ylönen, a researcher at Helsinki University of Technology, Finland, designed the first version of the protocol (now called SSH-1), prompted by a password-sniffing attack at his university network.

The Mythical Man-Month was republished in an anniversary edition with four extra chapters in 1995

Ken Schwaber and Jeff Sutherland formally presented the Scrum framework at the OOPSLA '95 conference in Austin, Texas, in 1995.

1996

UTF-8 was first formally standardized in January 1996 as RFC 2044, defining it as a transformation format for encoding Unicode characters for use in MIME and Internet protocols while preserving US-ASCII compatibility.

Netscape Navigator 2.0 was released in March 1996 with Java Applet support via the NPAPI plugin architecture, making applets broadly accessible and sparking their rapid adoption across the web.

Debian first stable version (1.1) was released on June 17, 1996.

PostgreSQL, also known as Postgres, is a free and open-source relational database management system (RDBMS) emphasizing extensibility and SQL compliance. It was first released as an open-source project on July 8, 1996, and on October 22, 1996, the website PostgreSQL.org was launched as the project was officially renamed to reflect its SQL support.

Cascading Style Sheets (CSS) is a style sheet language used for describing the presentation of a document written in a markup language such as HTML or XML, with initial release on December 17, 1996.

The Open Group is a global consortium that seeks to "enable the achievement of business objectives" by developing "open, vendor-neutral technology standards and certifications." It was established in 1996 when X/Open merged with the Open Software Foundation.

Objective Caml (OCaml) was first released in 1996, when Didier Rémy and Jérôme Vouillon integrated a powerful, statically type-safe object and class system into Caml Special Light, giving the language its "Objective" prefix.

IntelliSense is Microsoft’s implementation of code completion, best known in Visual Studio. It was first introduced as a feature of a mainstream Microsoft product in 1996 building on many already invented concepts of code completion and syntax checking.

Microsoft launched ActiveX in 1996 as a rebranded and simplified set of COM-based technologies specifically optimized for the web and integration with Internet Explorer.

HTTP/1 was finalized and fully documented (as version 1.0) in 1996.

In 1996, the iframe tag was introduced by Internet Explorer; like the object element, it can load or fetch content asynchronously.

Newer versions of SSL/TLS are based on SSL 3.0, released in 1996.

In December 1996, Macromedia acquired FutureWave Software and rebranded FutureSplash Animator as Macromedia Flash 1.0, distributing Flash Player as a free browser plugin to rapidly gain market share and establish Flash as the dominant platform for interactive web content.

1997

PostgreSQL 6.0 was released on January 29, 1997, as the first formal release under the new name, introducing unique indexes and the pg_dumpall utility.

Apple Computer acquired NeXT for $427 million on February 4, 1997, gaining the OPENSTEP operating system and bringing Steve Jobs back to Apple. The NeXTSTEP-derived codebase would serve as the foundation for Mac OS X.

Visual Studio is an integrated development environment (IDE) from Microsoft used to develop computer programs, websites, web apps, web services and mobile apps. Microsoft first released Visual Studio on March 19, 1997, bundling many of its programming tools together for the first time as Visual Studio 97.

The essay "The Cathedral and the Bazaar" by Eric S. Raymond was first presented at the Linux Kongress on May 27, 1997

The first edition of ECMA-262 (ECMAScript) was adopted by the Ecma General Assembly in June 1997.

The unified modeling language (UML) is a general-purpose visual modeling language that is intended to provide a standard way to visualize the design of a system. UML 1.1 was submitted to the OMG in August 1997 and adopted by the OMG in November 1997.

The Comprehensive R Archive Network (CRAN) is R’s central software repository, supported by the R Foundation. CRAN was created by Kurt Hornik and Friedrich Leisch in 1997, with the name paralleling other early packing systems such as TeX’s CTAN (released 1992) and Perl’s CPAN (released 1995).

Zeev Suraski and Andi Gutmans rewrote the parser in 1997 and formed the base of PHP 3, changing the language’s name to the recursive acronym PHP: Hypertext Preprocessor.

A recurrent neural network (RNN) is a class of artificial neural networks where connections between nodes can create a cycle, allowing output from some nodes to affect subsequent input to the same nodes. This allows it to exhibit temporal dynamic behavior. Long short-term memory (LSTM) networks were invented by Hochreiter and Schmidhuber in 1997 and set accuracy records in multiple applications domains.

Google Search is a search engine operated by Google that uses algorithms to analyze and rank websites based on their relevance to the search query, launched in 1997.

JUnit was created by Kent Beck and Erich Gamma during a flight from Zurich to OOPSLA 1997 in Atlanta, porting Beck's SUnit framework to Java using pair programming and test-first development. It became the dominant testing framework for Java and established automated unit testing as a standard engineering practice.

1998

Netscape Communications Corporation announced on January 22, 1998, that it would release the source code for its flagship Netscape Communicator product as free software.

Extensible Markup Language (XML) is a markup language and file format for storing, transmitting, and reconstructing arbitrary data, defining a set of rules for encoding documents in a format that is both human-readable and machine-readable. It was first published on February 10, 1998.

The Open Source Initiative (OSI) is the steward of the Open Source Definition, the set of rules that define open source software. The organization was founded in late February 1998 by Bruce Perens and Eric S. Raymond, part of a group inspired by Netscape's announcement to open-source its browser suite.

Netscape Communications Corporation released the source code for Netscape Communicator and started the Mozilla project on March 31, 1998, influenced by "The Cathedral and the Bazaar"

Advanced package tool, or APT, is a free-software user interface that works with core libraries to handle the installation and removal of software on Debian and Debian-based Linux distributions, with initial release on March 31, 1998.

The iMac G3 began shipping on August 15, 1998, featuring a translucent Bondi Blue enclosure designed by Jony Ive. It dropped legacy ports like SCSI and floppy drives in favor of USB, and is widely credited with saving Apple from near-bankruptcy after Steve Jobs's return.

The Document Object Model (DOM) is a cross-platform and language-independent interface that treats an XML or HTML document as a tree structure wherein each node is an object representing a part of the document. It was first published on October 1, 1998.

OpenSSL is a software library for applications that secure communications over computer networks against eavesdropping or need to identify the party at the other end, widely used by Internet servers including the majority of HTTPS websites. The OpenSSL project was founded in 1998 to provide a free set of encryption tools for the code used on the Internet, with initial release on December 23, 1998.

LAMP (Linux, Apache, MySQL, PHP/Perl/Python) is an acronym denoting one of the most common software stacks for many of the web's most popular applications. The acronym LAMP was coined by Michael Kunze in the December 1998 issue of Computertechnik, a German computing magazine, as he demonstrated that a bundle of free and open-source software "could be a feasible alternative to expensive commercial packages".

In 1998, the Ruby Application Archive was launched by Matsumoto, along with a simple

English-language homepage for Ruby.

The Halloween documents comprise a series of confidential Microsoft memoranda on potential strategies relating to free software, open-source software, and to Linux in particular, and a series of media responses to these memoranda. Both the leaked documents and the responses were published by open-source software advocate Eric S. Raymond in 1998.

In 1998, the Microsoft Outlook Web Access team developed the concept behind the XMLHttpRequest scripting object. XMLHttpRequest (XHR) is an API in the form of an object whose methods transfer data between a web browser and a web server. The object is provided by the browser’s JavaScript environment.

AppArmor ("Application Armor") is a Linux kernel security module that allows the system administrator to restrict programs' capabilities with per-program profiles allowing capabilities like network access, raw socket access, and the permission to read, write, or execute files on matching paths. It was initially released in 1998.

Perl 5 gained widespread popularity in the late 1990s as a CGI scripting language, in part due to its powerful regular expression and string parsing abilities.

Between 1998 and 2004, CFEngine grew in adoption along with the popularity of Linux as a computing platform.

1999

TLS 1.0 was first defined in RFC 2246 in January 1999 as an upgrade of SSL Version 3.0.

Mac OS X Server 1.0 was released on March 16, 1999, as the first operating system from Apple built on the NeXTSTEP codebase acquired from NeXT. It used a modified version of the classic Mac OS GUI and served as a precursor to the consumer Mac OS X.

Salesforce, Inc. is an American cloud-based software company headquartered in San Francisco, California. It provides applications focused on sales, customer service, marketing automation, e-commerce, analytics, artificial intelligence, and application development. Salesforce was founded on March 8, 1999 by former Oracle executive Marc Benioff, together with Parker Harris, Dave Moellenhoff, and Frank Dominguez as a software-as-a-service (SaaS) company.

The Apache Software Foundation (ASF) is an American nonprofit corporation to support a number of open source software projects. The ASF was formed from a group of developers of the Apache HTTP Server, and incorporated on March 25, 1999.

The Melissa virus was a fast-spreading macro virus that first appeared around March 26, 1999. The virus mainly attacked computers using Microsoft Word and Outlook.

HotSpot, released as Java HotSpot Performance Engine, is a Java virtual machine for desktop and server computers, developed by Sun Microsystems and now maintained and distributed by Oracle Corporation. It features improved performance via methods such as just-in-time compilation and adaptive optimization. The Java HotSpot Performance Engine was released on April 27, 1999, built on technologies from an implementation of the

programming language Smalltalk named Strongtalk. Initially available as an add-on for Java 1.2, HotSpot became the default Sun JVM in Java 1.3.

VMware Workstation Pro (known as VMware Workstation until release of VMware Workstation 12 in 2015) is a hosted hypervisor that runs on x64 versions of Windows and Linux operating systems, with initial release on May 15, 1999.

RRDtool (round-robin database tool) aims to handle time series data such as network bandwidth, temperatures or CPU load, with initial release on July 16, 1999.

GnuPG was initially developed by Werner Koch, with the first production version (1.0.0) released on September 7, 1999, almost two years after the first GnuPG release (version 0.0.0).

In 1999, the Haskell 98 Report was published, defining a stable, minimal, and portable version of the language.

Extreme programming (XP) is a software development methodology intended to improve software quality and responsiveness to changing customer requirements. Kent Beck developed extreme programming during his work. He began to refine the development methodology used in the project and wrote a book on the methodology (Extreme Programming Explained, published in October 1999).

The Pragmatic Programmer: From Journeyman to Master is a book about computer programming and software engineering, written by Andrew Hunt and David Thomas and published in October 1999.

GNU nano is a text editor for Unix-like computing systems or operating environments using a command line interface, with initial release on November 18, 1999.

OpenBSD 2.6 was released on December 1, 1999, featuring the first release of OpenSSH. Originally developed as a free replacement for the proprietary SSH suite, OpenSSH is based on the Secure Shell (SSH) protocol and provides a secure channel over an unsecured network in a client–server architecture.

Jakarta EE, formerly Java Platform, Enterprise Edition (Java EE) and Java 2 Platform, Enterprise Edition (J2EE), is a set of specifications extending Java SE with specifications for enterprise features such as distributed computing and web services, with initial specification release on December 17, 1999.

Peopleware: Productive Projects and Teams was revised for its 2nd Edition in 1999

The book *The Cathedral and the Bazaar* was published in 1999 and was released under the Open Publication License v2.0 in the same year.

Nikolai Bezroukov published two critical essays on Eric Raymond’s views of open source software in 1999

SourceForge, founded in 1999 by VA Software, was the first provider of a centralized location for free and open-source software developers to control and manage software development

and offering this service without charge.

Timeline - 2000-09

2000

Flash 5, released in 2000, introduced ActionScript 1.0 — a full scripting language based on ECMAScript — enabling complex interactivity and turning Flash into a platform for rich internet applications, games, and video players.

The jail mechanism is an implementation of FreeBSD's OS-level virtualisation that allows system administrators to partition a FreeBSD-derived computer system into several independent mini-systems called jails, first introduced in FreeBSD version 4.0 on March 14, 2000. Jails aim at three primary goals: virtualization, security, and ease of delegation.

On 22 May 2000, PHP 4, powered by the Zend Engine 1.0, was released.

SQLite is a database engine written in the C programming language, first released on August 17, 2000. It is not a standalone app but a library that software developers embed in their apps, making it the most widely deployed database engine in the world.

Python 2.0 was released on 16 October 2000 with many major new features, including a cycle-detecting garbage collector and support for Unicode.

Apache Subversion (SVN) is a software versioning and revision control system. CollabNet founded the project in 2000 to write an open-source version-control system that operated like CVS but fixed its bugs and added missing features, with its first release on October 20, 2000.

Security-Enhanced Linux (SELinux) is a Linux kernel security module that provides a mechanism for supporting access control security policies, including mandatory access controls (MAC). It was first released on December 22, 2000.

C# (pronounced see sharp) is a general-purpose, multi-paradigm programming language designed by Anders Hejlsberg at Microsoft in 2000. It was later approved as an international standard by Ecma (ECMA-334) in 2002 and ISO/IEC (ISO/IEC 23270) in 2003.

CMake is a cross-platform build system generator developed in response to the need for a unified build environment for the Insight Segmentation and Registration Toolkit (ITK), first implemented in 2000 and further developed in 2001.

The Linux Foundation (LF) is a non-profit technology consortium founded in 2000 as a merger between Open Source Development Labs and the Free Standards Group to standardize Linux, support its growth, and promote its commercial adoption.

In 2000, Roy Fielding proposed Representational State Transfer (REST) as an architectural approach to designing web services. REST is an architectural style for building distributed systems based on hypermedia.

Microsoft officially announced the .NET initiative at the Forum 2000 conference in June 2000, presenting a new "managed" software platform intended to address the complexities

of binary-level component models like COM.

2001

Toyota formalized its internal management values as "The Toyota Way" in 2001, consisting of two main pillars: Continuous Improvement (Kaizen) and Respect for People.

Linux version 2.4.0, released on 4 January 2001, contained support for ISA Plug and Play, USB, and PC Cards. Linux 2.4 added support for the Pentium 4 and Itanium, and for the newer 64-bit MIPS processor.

Creative Commons (CC) is an American non-profit organization and international network devoted to educational access and expanding the range of creative works available for others to build upon legally and to share, founded on January 15, 2001.

Wikipedia is a free online encyclopedia created and edited by volunteers around the world. It was founded on January 15, 2001, by Jimmy Wales and Larry Sanger, based on the principle of creating a comprehensive, accessible, and reliable source of information that anyone could edit. Wikipedia runs on MediaWiki, software created specifically for Wikipedia’s needs.

On February 11-13, 2001, seventeen software industry leaders met to talk, ski, relax, and try to find common ground, and together published the Manifesto for Agile Software Development, which counts Scrum co-creators Ken Schwaber and Jeff Sutherland among its signatories.

VMware ESXi (formerly ESX), an enterprise-class type-1 hypervisor developed by VMware for deploying and serving virtual computers, was first released on March 23, 2001.

Mac OS X 10.0 Cheetah was released on March 24, 2001, as the first desktop version of Apple’s Unix-based operating system built on the NeXTSTEP foundation. It introduced the Aqua user interface, replacing the classic Mac OS look and feel.

CruiseControl, a Java-based continuous build framework distributed under a BSD-style license, was first released on March 30, 2001 as one of the earliest open-source continuous integration tools.

PostgreSQL 7.1, released on April 13, 2001, introduced the Write-Ahead Log (WAL), a critical feature for ensuring data durability and crash recovery.

YAML is a human-readable data-serialization language commonly used for configuration files and data storage or transmission. It was first released on May 11, 2001.

reStructuredText (RST) is a file format for textual data used primarily in the Python community for technical documentation. Part of the Docutils project, it was first released on June 1, 2001 to provide Python with documentation tools similar to Javadoc for Java.

WebKit is a browser engine developed by Apple and primarily used in its Safari web browser and all iOS web browsers, started by Don Melton within Apple on June 25, 2001 as a fork of KHTML and KJS.

Code Red was a computer worm observed on the Internet on July 15, 2001 that attacked computers running Microsoft’s IIS web server, becoming the first large-scale mixed-threat attack to successfully target enterprise networks.

The Nimda virus is a malicious file-infecting computer worm that quickly spread, surpassing the economic damage caused by previous outbreaks such as Code Red, with the first released advisory appearing on September 18, 2001.

Windows XP, launched on October 25, 2001, finally merged Microsoft’s consumer and business operating systems by moving the consumer line onto the stable NT kernel, featuring a redesigned "Luna" interface that would dominate the desktop market for over a decade.

Eclipse is an integrated development environment (IDE) with a base workspace and an extensible plug-in system, inspired by the Smalltalk-based VisualAge family of IDEs. Eclipse 1.0 was released on November 29, 2001, and was the most popular Java IDE until 2016.

SciPy is a free and open-source Python library for scientific and technical computing created around 2001 when Travis Oliphant, Eric Jones, and Pearu Peterson merged code they had written and unified it under a single package name.

VMware Server (formerly VMware GSX Server) is a discontinued free-of-charge virtualization software server suite developed by VMware, Inc., with both ESX 1.0 (Type 1 hypervisor) and GSX 1.0 (Type 2 hypervisor) launching in 2001.

IPython (Interactive Python) is a command shell for interactive computing originally developed for Python, offering introspection, rich media, shell syntax, tab completion, and history. It was first released in 2001.

SHA-2 (Secure Hash Algorithm 2) is a set of cryptographic hash functions designed by the United States National Security Agency (NSA) and first published in 2001, built using the Merkle–Damgård construction from a one-way compression function itself based on the Davies–Meyer structure from a specialized block cipher.

The Advanced Encryption Standard (AES), also known by its original name Rijndael, is a specification for the encryption of electronic data established by the U.S. National Institute of Standards and Technology (NIST) in 2001.

2002

ASP.NET is a server-side web-application framework for building dynamic web pages, first released on January 5, 2002 as part of the .NET Framework 1.0. It is the successor to Microsoft’s Active Server Pages (ASP) technology.

NET Framework 1.0 was officially released on February 13, 2002, alongside Visual Studio .NET, introducing the Common Language Runtime (CLR) and the C# programming language.

Arch Linux is an independently developed, x86-64 general-purpose Linux distribution that strives to provide the latest stable versions of most software by following a rolling-release model. It was started by Judd Vinet and first released on March 11, 2002.

Gentoo Linux is a Linux distribution built using the Portage package management system, with version 1.0 released on March 31, 2002, and the non-profit Gentoo Foundation established in 2004 with all copyrights and trademarks transferred to it.

The Mozilla project developed and implemented an interface called nsIXMLHttpRequest into the Gecko layout engine, creating a wrapper that exposed it as the XMLHttpRequest JavaScript object. The XMLHttpRequest object was accessible as early as Gecko version 0.6 (released December 6, 2000) but was not completely functional until Gecko 1.0 (released June 5, 2002).

Mozilla Firefox is a free and open-source web browser developed by the Mozilla Foundation, using the Gecko rendering engine to display web pages. It was first released on September 23, 2002.

The Spring Framework is an application framework and inversion of control container for the Java platform, first released on October 1, 2002. Its core features can be used by any Java application, with extensions for building web applications on top of Java EE.

Torch is an open-source machine learning library and scientific computing framework based on the Lua programming language, first released in October 2002.

The Linux Namespaces originated in 2002 in the 2.4.19 kernel with work on the mount namespace kind. Additional namespaces were added beginning in 2006 and continuing into the future.

AsciiDoc is a human-readable document format semantically equivalent to DocBook XML but using plain-text markup conventions, created in 2002 by Stuart Rackham along with Python-based tools (‘asciidoc’ and ‘a2x’) for converting plain-text files to commonly used published document formats.

JSON is a language-independent data format derived from JavaScript, with the JSON.org website launched in 2002 to establish it as a standard data interchange format.

The final major release of the software, Lotus 1-2-3 Release 9.8, was launched in 2002 as part of the Lotus SmartSuite office package.

Ken Schwaber founded the Scrum Alliance in 2002 to provide worldwide Scrum training and certification.

Kent Beck published Test Driven Development: By Example on November 8, 2002, formalising TDD as a standalone practice with the red-green-refactor cycle: write a failing test, make it pass with minimal code, then refactor.

2003

Tableau Software, LLC is an American interactive data visualization software company focused on business intelligence, formally founded in January 2003 by Pat Hanrahan, Christian Chabot, and Chris Stolte, with its headquarters moving to Seattle, Washington in 2004.

The first public demonstration of Monad (Microsoft Shell or MSH) occurred in September 2003 at the Professional Developers Conference (PDC).

Android, Inc. was founded in Palo Alto, California, in October 2003 by Andy Rubin, Rich Miner, Nick Sears, and Chris White to develop "smarter mobile devices that are more aware of its owner's location and preferences"

Linux Version 2.6.0 was released on 17 December 2003. The development for 2.6.x changed further towards including new features throughout the duration of the series.

The Python Package Index (PyPI), also known as the Cheese Shop, is the official third-party software repository for Python, launched in 2003. Its metadata standard was defined by PEP 241 in March 2001, with the comprehensive catalog proposal finalized in November 2002.

Domain-driven design (DDD) is a major software design approach focusing on modeling software to match a domain according to input from domain experts, with the term coined by Eric Evans in his book of the same name published in 2003.

Google Borg is a cluster manager used by Google. It led to widespread use of similar approaches such as Docker and Kubernetes. According to the research paper published by Google in 2015, Borg was developed in 2003.

Xen is a type-1 hypervisor that provides services allowing multiple computer operating systems to execute on the same hardware concurrently, originating as a research project at the University of Cambridge led by Ian Pratt and his PhD student Keir Fraser. The first public release was made in 2003, with v1.0 following in 2004, and the project is now developed by the Linux Foundation.

Matplotlib is a plotting library for the Python programming language and NumPy, providing an object-oriented API for embedding plots into applications using GUI toolkits like Tkinter, wxPython, Qt, or GTK. It was first released in 2003.

A CAPTCHA (Completely Automated Public Turing test to tell Computers and Humans Apart) is a challenge–response Turing test used in computing to determine whether a user is human and to deter bot attacks and spam, with the term coined in 2003 by Luis von Ahn, Manuel Blum, Nicholas J. Hopper, and John Langford.

RFC 3629 was published in November 2003, updating the UTF-8 specification to restrict it to the range U+0000..U+10FFFF and establishing UTF-8 as a standard Internet protocol element.

Dan North introduced behaviour-driven development (BDD) in late 2003 while writing JBehave, a replacement for JUnit that removed testing vocabulary in favour of one centred on verifying behaviour. Together with Chris Matts he extended the approach to requirements via the "Given/When/Then" scenario vocabulary.

2004

Scala is a strong statically typed general-purpose programming language supporting both object-oriented and functional programming paradigms, first released on January 20, 2004.

The Web Hypertext Application Technology Working Group (WHATWG) was announced on June 4, 2004, founded by Apple, Mozilla, and Opera after the W3C rejected their joint proposal for evolving HTML at a workshop. WHATWG began independently developing a new HTML specification that would eventually become HTML5.

RubyGems is a package manager for the Ruby programming language that provides a standard format for distributing Ruby programs and libraries, with development starting in November 2003 and public release on March 14, 2004 (Pi Day).

In April 2004, Windows Installer XML (WiX) was the first Microsoft project to be released under an open-source license, the Common Public License. Initially hosted on SourceForge, it was also the first Microsoft project to be hosted externally.

In April 2004, South African entrepreneur Mark Shuttleworth invited a dozen Debian developers to his London flat, where they brainstormed and laid out the distinguishing features of what would become Ubuntu. To fund the project, Shuttleworth created Canonical Ltd. to employ the developers using his fortune from selling Thawte to Verisign.

Google launched Gmail in a limited beta release on April 1, 2004, offering one gigabyte of storage—significantly more than competitors at the time

On 1 July 2004, PHP 5 was released, powered by the new Zend Engine II. PHP 5 included new features such as improved support for object-oriented programming, the PHP Data Objects (PDO) extension, and numerous performance enhancements.

Maven is a build automation tool used primarily for Java projects. Created by Jason van Zyl, it began as a sub-project of Apache Turbine in 2002 and was accepted as a top-level Apache Software Foundation project in 2003. Maven 1.0 was released on July 13, 2004.

Ruby on Rails 0.5.0, the initial open-source release extracted from the project management tool Basecamp, was first released by David Heinemeier Hansson in July 2004.

Nginx is a web server that can also be used as a reverse proxy, load balancer, and HTTP cache. Created by Igor Sysoev to solve the C10k problem, it was first publicly released on October 4, 2004 and was serving 500 million requests per day for the Rambler portal by September 2008.

Ubuntu 4.10 (Warty Warthog) was released on 20 October 2004 as the inaugural release of Ubuntu. It was built upon Debian, with plans for a new release every six months and eighteen months of support thereafter.

Unionfs is a filesystem service for Linux, FreeBSD and NetBSD which implements a union mount for other file systems, allowing files and directories of separate file systems to be transparently overlaid into a single coherent file system. Version 1.0.2 was released on November 9, 2004.

Version 1.0 of Firefox was released on November 9, 2004. This was followed by version 1.5 in November 2005, version 2.0 in October 2006, version 3.0 in June 2008, version 3.5 in June 2009.

Markdown is a lightweight markup language for creating formatted text using a plain-text editor. John Gruber and Aaron Swartz created Markdown in 2004 as a markup language that is intended to be easy to read in its source code form.

MapReduce is a programming model and an associated implementation for processing and generating big data sets with a parallel, distributed algorithm on a cluster, introduced by Google in 2004.

In 2004, K. S. Oh and K. Jung demonstrated that standard neural networks can be greatly accelerated on GPUs, achieving implementations 20 times faster than CPU equivalents, with subsequent papers in 2005 further emphasizing the value of GPGPU for machine learning.

Selenium was created in 2004 by Jason Huggins at ThoughtWorks in Chicago as "JavaScriptTestRunner" to automate testing of an internal time-and-expenses application. Fellow ThoughtWorker Paul Hammant proposed open-sourcing it and co-developed Selenium Remote Control (RC), enabling browser automation from any language over the wire.

2005

PostgreSQL 8.0 was released on January 19, 2005, notable for being the first version with native Microsoft Windows support, as well as adding savepoints and point-in-time recovery.

Hudson, a continuous integration server written in Java, was created by Kohsuke Kawaguchi at Sun Microsystems and first released on February 7, 2005. After Oracle acquired Sun in 2010, a trademark dispute led the community to fork the project and rename it Jenkins in 2011.

The Prototype JavaScript Framework is a JavaScript framework created by Sam Stephenson in February 2005 as part of Ajax support in Ruby on Rails.

Security Assertion Markup Language (SAML) is an open standard for exchanging authentication and authorization data between parties, particularly between an identity provider and a service provider, with SAML 2.0 becoming an OASIS Standard in March 2005.

At WWDC on June 6, 2005, Steve Jobs announced Apple’s plan to transition the entire Macintosh line from PowerPC to Intel processors, marking the second major processor architecture transition in Mac history after the shift from Motorola 68000 to PowerPC in 1994.

collectd is a Unix daemon that collects, transfers and stores performance data of computers and network equipment, first released on July 8, 2005.

Google acquired Android, Inc. on July 11, 2005, making it a wholly owned subsidiary of Google and retaining the company’s key employees to continue development of the mobile operating system

Django is a free and open-source, Python-based web framework that follows the model–template–views (MTV) architectural pattern, first released on July 21, 2005.

RSpec was started in August 2005 by Steven Baker with Dave Astels, Aslak Hellesøy, and David Chelimsky as a behaviour-driven development (BDD) framework for Ruby. Inspired by JBehave, it introduced the describe/it DSL for expressing software behaviour as executable examples. RSpec 1.0 was released on May 18, 2007, after David Chelimsky took over project leadership in 2006.

In December 2005, Yahoo! began offering some of its Web services in JSON.

JSONP, or JSON-P (JSON with Padding), is a historical JavaScript technique for requesting data by loading a `<script>` element, which is an element intended to load ordinary JavaScript. JSONP enables sharing of data bypassing same-origin policy. The original proposal for JSONP, where the padding is a callback function, appears to have been made by Bob Ippolito in December 2005.

Ruby on Rails 1.0 was released on December 13, 2005, marking the framework's first major stable version.

F# (pronounced F sharp) is a functional-first, general-purpose, strongly typed, multi-paradigm programming language developed by the F# Software Foundation, Microsoft, and open contributors, first released in 2005.

Git was created by Linus Torvalds in 2005 for Linux kernel development with contributions from other kernel developers, with maintenance transferred to Junio Hamano on 26 July 2005. Hamano released version 1.0 on 21 December 2005 and has remained the project's core maintainer.

Puppet is a configuration management tool founded by Luke Kanies in 2005, using a declarative language to manage the IT infrastructure lifecycle including provisioning, patching, and configuration. Puppet itself is written in Ruby, first released in 2005.

Adobe Systems acquired Macromedia on December 3, 2005, for approximately $3.4 billion, taking ownership of Flash, Dreamweaver, Director, Fireworks, and Authorware. The product was subsequently rebranded as Adobe Flash.

2006

On January 10, 2006, Steve Jobs introduced the first Intel-based Macs — the iMac and MacBook Pro — at Macworld Conference & Expo, beginning a transition from PowerPC that would be completed across the entire product line within nine months.

SQLAlchemy is an open-source SQL toolkit and object-relational mapper for the Python programming language. It was first released in February 2006.

Amazon S3 (Amazon Simple Storage Service) is an object storage service offered by Amazon Web Services (AWS) through a web service interface, launched in the United States on March 14, 2006.

Apache Hadoop, a framework for distributed processing of large data sets across clusters of computers, was created by Doug Cutting and Mike Cafarella and first released on April 1, 2006. Inspired by Google's MapReduce and Google File System papers, its core consists of

the Hadoop Distributed File System (HDFS) and a MapReduce processing model. Cutting named it after his son’s toy stuffed elephant.

On 5 April 2006, the World Wide Web Consortium (W3C) released the first draft specification for the XMLHttpRequest object in an attempt to create an official Web standard.

Microsoft officially renamed Monad to Windows PowerShell on April 25, 2006, and released the first Release Candidate (RC1) for the tool.

Upstart was an event-based replacement for the traditional init daemon, first released on August 24, 2006, used by several Unix-like operating systems to perform tasks when the computer is started.

Amazon Elastic Compute Cloud (EC2) is a cloud computing service within Amazon Web Services (AWS) that allows users to rent virtual computers for running their applications, announced in limited public beta on August 25, 2006 and initially using Xen virtualization exclusively.

Apple announced on August 7, 2006, that it would ship Ruby on Rails with Mac OS X v10.5 "Leopard," which was later released in October 2007 as the first major operating system to pre-install the framework.

jQuery is a JavaScript library designed to simplify HTML DOM traversal and manipulation, event handling, CSS animation, and Ajax. Created by John Resig at BarCamp NYC in January 2006, inspired by Dean Edwards' cssQuery library, it was first released on August 26, 2006.

Windows PowerShell 1.0 was released on November 14, 2006, for Windows XP SP2, Windows Server 2003, and Windows Vista.

NumPy is a library for the Python programming language that adds support for large multi-dimensional arrays and matrices along with high-level mathematical functions, created in 2006 when Travis Oliphant unified the community around a single array package by porting Numarray’s features to Numeric as part of the SciPy project.

In 2006, Geoffrey Hinton developed the deep belief network technique for training many-layered deep autoencoders.

In 2006, a revised version of the SSH protocol, SSH-2, was adopted as a standard, introducing incompatibilities with the original SSH-1 protocol.

Dan North published "Introducing BDD" in 2006, coining the term behaviour-driven development and formalising the Given/When/Then scenario structure as a bridge between business stakeholders and developers.

2007

On April 10, 2007, Mozilla, Apple, and Opera proposed that the W3C’s new HTML Working Group adopt the WHATWG’s HTML5 draft as its starting point, formally uniting the two parallel standardization efforts under the HTML5 name.

Steve Jobs unveiled the first-generation iPhone, running what was then marketed as a version of "OS X," during his keynote address at the Macworld Conference & Expo on January 9, 2007.

Apache Groovy is a Java-syntax-compatible, statically and dynamically typed object-oriented programming language for the Java platform with features similar to Python, Ruby, and Smalltalk, first discussed by James Strachan in August 2003 and formally released as version 1.0 on January 2, 2007 following Java Community Process standardization efforts.

Simon Stewart pushed the initial commit of WebDriver on January 3, 2007, developing a browser automation tool that controlled browsers natively rather than through injected JavaScript, overcoming the security sandbox limitations of Selenium RC.

Oracle VM VirtualBox (formerly Sun VirtualBox and Innotek VirtualBox) is a type-2 hypervisor for x86 virtualization developed by Oracle Corporation, first released on January 17, 2007.

Excel 2007, released on January 30, 2007, introduced the Ribbon interface and the new XML-based file format .xlsx, replacing the binary .xls format used in previous versions.

Kernel-based Virtual Machine (KVM) is a virtualization module in the Linux kernel that allows the kernel to function as a hypervisor. It was merged into the mainline Linux kernel in version 2.6.20, which was released on February 5, 2007.

Sun released the Java HotSpot virtual machine and compiler as free software under the GNU General Public License on November 13, 2006, with a promise that the rest of the JDK (which includes the Java Runtime Environment) would be placed under the GPL by March 2007.

Rake is a Make-like build automation program implemented in Ruby, where tasks and dependencies are specified in standard Ruby syntax. Version 0.7.3 was released on April 21, 2007.

OpenJDK (Open Java Development Kit) is a free and open-source implementation of Java SE, the result of an effort Sun Microsystems began in 2006. It produces the HotSpot virtual machine, the Java Class Library, and the javac compiler, with its first release on May 8, 2007.

The scikit-learn project started as scikits.learn, a Google Summer of Code project by French data scientist David Cournapeau, first released in June 2007.

iPhone OS 1, the first version of Apple’s mobile operating system, was released alongside the original iPhone on June 29, 2007.

Heroku was founded in June 2007 by James Lindenbaum, Adam Wiggins, and Orion Henry as a cloud platform-as-a-service (PaaS) initially supporting Ruby web applications, with the prototype taking around six months to develop. The platform received $3 million in funding in May 2008.

PyPy is an alternative implementation of the Python programming language to CPython (the standard implementation) that often runs faster due to its just-in-time compiler, starting as a

research project and reaching a mature 1.0 release in mid-2007 with a subsequent focus on production-readiness and enhanced CPython compatibility.

Sinatra was created and open-sourced by Blake Mizerany on September 9, 2007, as a lightweight Domain Specific Language (DSL) for building web applications in Ruby.

Development of the GitHub.com platform began on October 19, 2007. The site was launched in April 2008 by Tom Preston-Werner, Chris Wanstrath, P. J. Hyett and Scott Chacon after it had been made available for a few months prior as a beta release.

Language Integrated Query (LINQ) is a Microsoft .NET Framework component that adds native data querying capabilities to .NET languages, originally released as a major part of .NET Framework 3.5 on 19 November 2007.

The C# language v3.0, released in November 2007 with .NET Framework v3.5, also has full support of anonymous functions.

F# added asynchronous workflows with await points in version 2.0 in 2007. This influenced the async/await mechanism added to C#.

Go was conceived in the second half of 2007 at Google by Robert Griesemer, Rob Pike, and Ken Thompson, motivated by dissatisfaction with the complexity and slow compilation times of C++.

2008

Pandas is a Python library for data manipulation and analysis, offering data structures and operations for manipulating numerical tables and time series. It was first released on January 11, 2008.

HTML5 is a markup language used for structuring and presenting content on the World Wide Web. The first public W3C draft was released on January 22, 2008, introducing landmark features including `<canvas>`, `<video>`, `<audio>`, local storage, geolocation, Web Workers, and WebSockets — collectively enabling rich web applications without browser plugins.

The control groups functionality was merged into the Linux kernel mainline in kernel version 2.6.24, which was released in January 2008.

FreeBSD 7.0-RELEASE was released on February 27, 2008. This version added experimental support for the ZFS file system and introduced the ULE scheduler to improve performance on multi-core systems.

Sphinx is a documentation generator written in Python and widely used by the Python community, first released on March 21, 2008. It converts reStructuredText files into HTML websites and other formats including PDF, EPub, Texinfo, and man pages.

HBase is an open-source non-relational distributed database modeled after Google's Bigtable and written in Java, first released on March 28, 2008. It runs on top of HDFS or Alluxio as part of the Apache Hadoop project, providing Bigtable-like capabilities for Hadoop.

Gradle is a build automation tool for multi-language software development, covering the full lifecycle from compilation and packaging to testing, deployment, and publishing. It was first released on April 21, 2008.

On April 7, 2008, Google announced App Engine, a platform for developing and hosting web applications in Google-managed data centers, which was the first cloud computing service from the company.

PDF was published as an open ISO standard on July 1, 2008, as ISO 32000-1:2008, ending Adobe's proprietary control over the format. The standardized version was based on PDF 1.7 and was approved by ISO Technical Committee 171.

iPhone OS 2 was released on July 11, 2008, introducing the App Store and support for third-party applications, which significantly expanded the platform's capabilities.

Jinja is a web template engine for the Python programming language. It was created by Armin Ronacher and is licensed under a BSD License, with its initial release on July 17, 2008.

Apache Cassandra is a free and open-source, distributed, wide-column store, NoSQL database management system designed to handle large amounts of data across many commodity servers, providing high availability with no single point of failure. It was initially released in July 2008.

Linux Containers (LXC), an operating-system-level virtualization method for running multiple isolated Linux systems on a single kernel, was first released on August 6, 2008. It combines the kernel's cgroups and namespace isolation to provide lightweight containers, and served as the foundation upon which Docker was originally built before Docker replaced it with its own libcontainer in 2014.

The domain name bitcoin.org was registered on 18 August 2008.

On August 20, 2008, Amazon added Elastic Block Store (EBS) to provide persistent storage, a critical feature that had been lacking since EC2's introduction.

TLS 1.2 was defined in RFC 5246 in August 2008.

Google Chrome is a cross-platform web browser developed by Google. It was first released on September 2, 2008, for Microsoft Windows, built with free software components from Apple WebKit and Mozilla Firefox.

V8 is the JavaScript execution engine which was initially built for Google Chrome. It was then open-sourced by Google in 2008, with its first version released at the same time as the first version of Chrome on September 2, 2008. Much of V8's development is strongly inspired by the Java HotSpot Virtual Machine developed by Sun Microsystems, with the newer execution pipelines being very similar to those of HotSpot's.

Stack Overflow is a question and answer website for computer programmers. It was launched on September 15, 2008, by Jeff Atwood, Joel Spolsky, and Jarrod Dixon. Stack Overflow has become the largest online community for programmers and serves as a central

repository of programming knowledge, allowing users to ask questions, provide answers, and vote on the quality of contributions.

Android 1.0, the first commercial version of the operating system, was released on September 23, 2008, featuring an integration with Google services and the introduction of the Android Market.

DuckDuckGo is an American software company focused on online privacy whose flagship product is a search engine named DuckDuckGo. It was launched on September 25, 2008.

Open Virtualization Format (OVF) is an open standard for packaging and distributing virtual appliances or, more generally, software to be run in virtual machines. It was initially released in September 2008.

On 31 October 2008, a link to a white paper authored by Satoshi Nakamoto titled Bitcoin: A Peer-to-Peer Electronic Cash System was posted to a cryptography mailing list.

Python 3.0 was released on 3 December 2008 as a major revision of the language that intentionally breaks backward compatibility to improve clarity and remove legacy complexity.

In 2008, Microsoft joined the Apache Software Foundation and co-founded the Open Web Foundation with Google, Facebook, Sun, IBM, Apache, and others.

Graphite is a free open-source software (FOSS) tool that monitors and graphs numeric time-series data such as the performance of computer systems. Graphite was developed by Orbitz Worldwide, Inc and released as open-source software in 2008.

UTF-8 became the most common character encoding on the World Wide Web in 2008, surpassing ASCII and other legacy encodings.

Cucumber was created in 2008 by Aslak Hellesøy as a replacement for the RSpec Story Runner (formerly RBehave), enabling plain-language Gherkin scenarios to be shared between developers and non-technical stakeholders. The name was suggested by Hellesøy's fiancée after he initially called the project "Stories."

2009

Progress Chef (formerly Chef) is a configuration management tool written in Ruby and Erlang. It uses a pure-Ruby, domain-specific language (DSL) for writing system configuration "recipes". It was initially released in January 2009.

Nakamoto implemented the bitcoin software as open-source code and released it in January 2009.

Cross-Origin Resource Sharing (CORS) is a mechanism that allows restricted resources on a web page to be requested from another domain outside the domain from which the first resource was served, with the draft specification renamed to its final form in March 2009.

Android 1.5 Cupcake was released on April 27, 2009, initiating the tradition of naming major versions after confectionery items and introducing key features like the on-screen keyboard

and support for third-party widgets.

WolframAlpha is an answer engine developed by Wolfram Research. The engine is based on Wolfram's earlier product Wolfram Mathematica, a technical computing platform. It was launched on May 18, 2009.

Homebrew is a free and open-source software package management system that simplifies the installation of software on Apple's operating system, macOS, as well as Linux. Originally written by Max Howell, the package manager has gained popularity in the Ruby on Rails community and earned praise for its extensibility. It was initially released on May 21, 2009.

Windows PowerShell 2.0 was released in July 2009 as an integral part of Windows 7 and Windows Server 2008 R2, introducing key features such as PowerShell Remoting and background jobs.

CommonJS is a project with the goal to establish conventions on the module ecosystem for JavaScript outside of the web browser. The project was started by Mozilla engineer Kevin Dangoor in January 2009 and initially named ServerJS. In August 2009, the project was renamed CommonJS to show the broader applicability of the APIs.

Amazon Relational Database Service (or Amazon RDS) is a distributed relational database service by Amazon Web Services (AWS). It was first released on October 22, 2009, supporting MySQL databases, followed by support for Oracle Database in June 2011, Microsoft SQL Server in May 2012, and PostgreSQL in November 2013.

Following the ambitious but often criticized Windows Vista (2007), Windows 7 was released on October 22, 2009, refining the user interface and significantly improving performance, leading to its widespread adoption in both corporate and home environments.

VMware Server reached its final release on October 26, 2009, after which VMware discontinued the product in favor of its commercial ESXi hypervisor.

MariaDB is a community-developed, commercially supported fork of the MySQL relational database management system (RDBMS), intended to remain free and open-source software under the GNU General Public License. It was initially released on October 29, 2009.

In January 2009, Heroku launched a new version of the platform after a three-month rebuild. In October 2009, Byron Sebastian joined as CEO.

Node.js was written initially by Ryan Dahl in 2009, about thirteen years after the introduction of the first server-side JavaScript environment, Netscape's LiveWire Pro Web. Dahl demonstrated the project at the inaugural European JSConf on November 8, 2009.

Go is a statically typed, compiled programming language designed at Google by Robert Griesemer, Rob Pike, and Ken Thompson. It was publicly announced on November 10, 2009, as an open-source project.

The Haskell 2010 standard was released in November 2009, building upon Haskell 98 with several new features and extensions.

DevOps as a term originated in 2009 following a talk at the O’Reilly Velocity Conference titled “10+ Deploys per Day: Dev and Ops Cooperation at Flickr.” John Allspaw and Paul Hammond walked through some of the pains in the current software development lifecycle.

In 2009, the first conference named devopsdays was held in Ghent, Belgium. The conference was founded by Belgian consultant, project manager and agile practitioner Patrick Debois.

Microsoft first began contributing to the Linux kernel in 2009.

Google Chrome 4 was the first browser to ship full WebSocket support enabled by default in December 2009, proving real-world feasibility of persistent bidirectional browser-server communication.

SPDY is an obsolete open-specification communication protocol developed for transporting web content. Google announced SPDY in late 2009 and deployed in 2010.

Unresolved directive in all.adoc - include::tmp/docs/timelines/2010-19.adoc[]

Unresolved directive in all.adoc - include::tmp/docs/timelines/2020-present.adoc[]