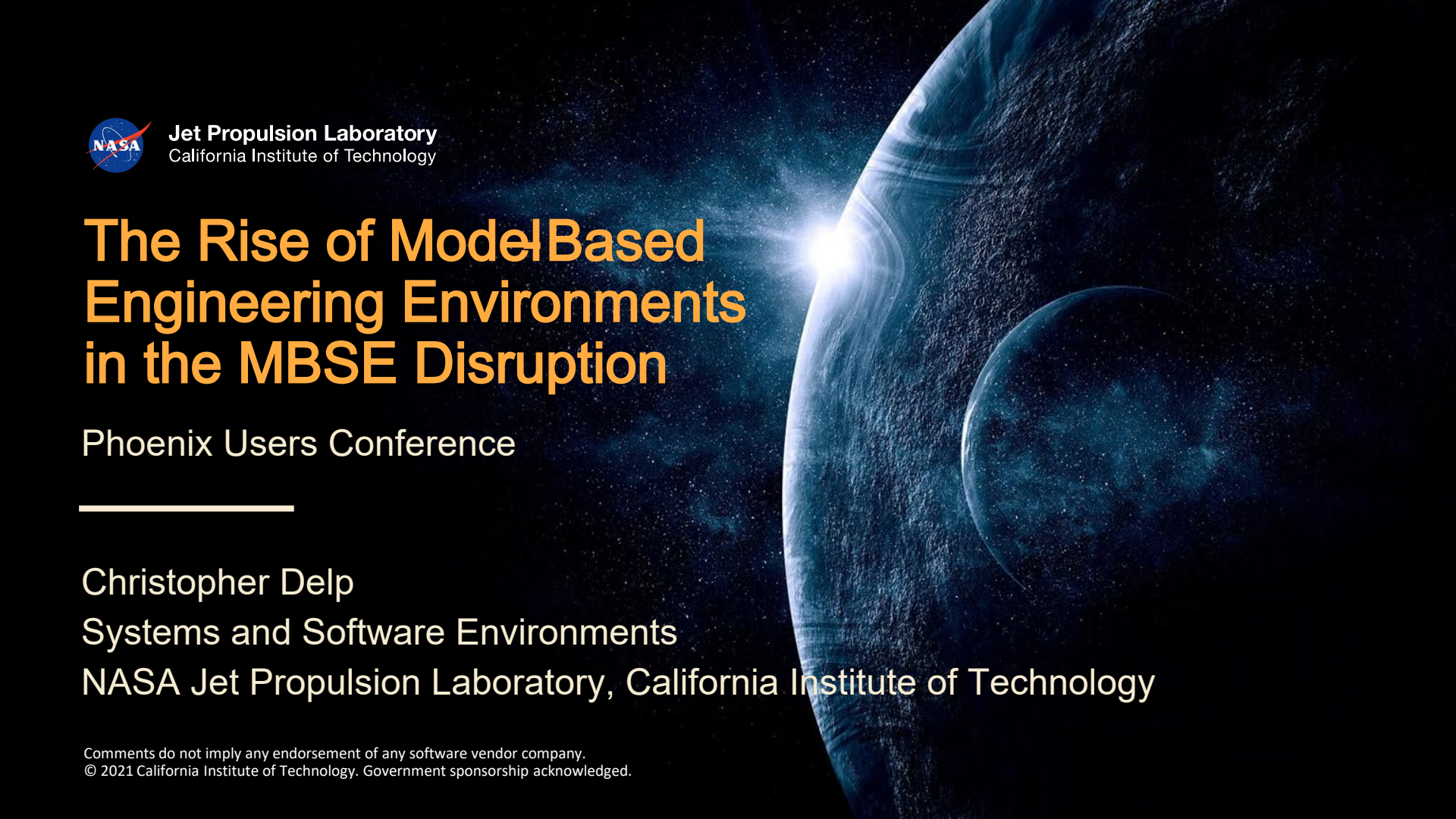


Jet Propulsion Laboratory
California Institute of Technology

The Rise of Model-Based Engineering Environments in the MBSE Disruption

Phoenix Users Conference

Christopher Delp
Systems and Software Environments
NASA Jet Propulsion Laboratory, California Institute of Technology

Comments do not imply any endorsement of any software vendor company.

Outline

- Introduction
- The Rise of the Model-Based Engineering Environments (MBEE)
- JPL Model-Based Engineering Environment
- Welcome to the World of Tomorrow

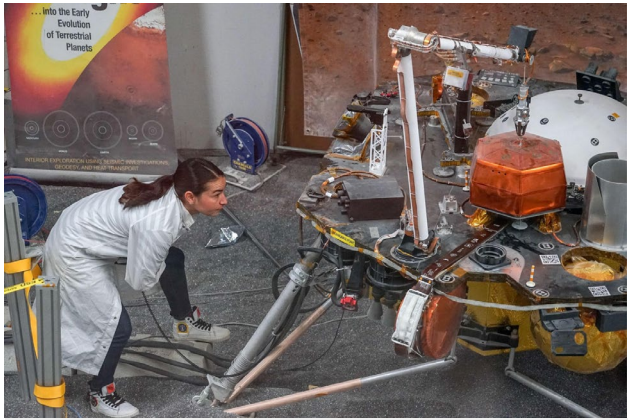
Introduction

PRESENTER

Christopher Delp

- Systems Engineering
- Software Development
- Safety Critical Software
- Model-Based Systems Engineering
- Model Based Engineering Environments

JPL is Part of NASA and Caltech



Federally-funded (NASA-owned) Research and Development Center (FFRDC)
University Operated (Caltech)
$2.7B Business Base
6,000 Employees

167 Acres (includes 12 acres leased for parking)
139 Buildings; 36 Trailers
673,000 Net Square Feet of Office Space
906,000 Net Square Feet of
Non-Office Space (e.g., Labs)

Some Notable Firsts

Surveyor 1, First soft landing on the moon

Viking, first landing on another planet

Continuous presence on Mars since 1997

Voyager 1, First interstellar traveler

JPL Vision – Dare Mighty Things

- Pursue long-term scientific Quests with a diverse and bold portfolio of missions
- Push the limits of space exploration technology by developing and fielding ever more capable autonomous robotic systems
- Strengthen our core expertise while developing and maintaining strategic partnerships with other NASA centers, U.S. national laboratories, academia, industry, and our international partners
- Build a robust Laboratory of the future that fosters a culture of innovation, openness, and inclusiveness
- Transform our systems to promote easier collaboration and information sharing
- Strengthen our end-to-end mission capabilities and accelerate the infusion of new technologies and capabilities into our future missions
- Inspire the world through our stories and our journey into space
- Support American leadership in space and as we Dare Ever Mightier Things

JPL Vision – Seven Quests

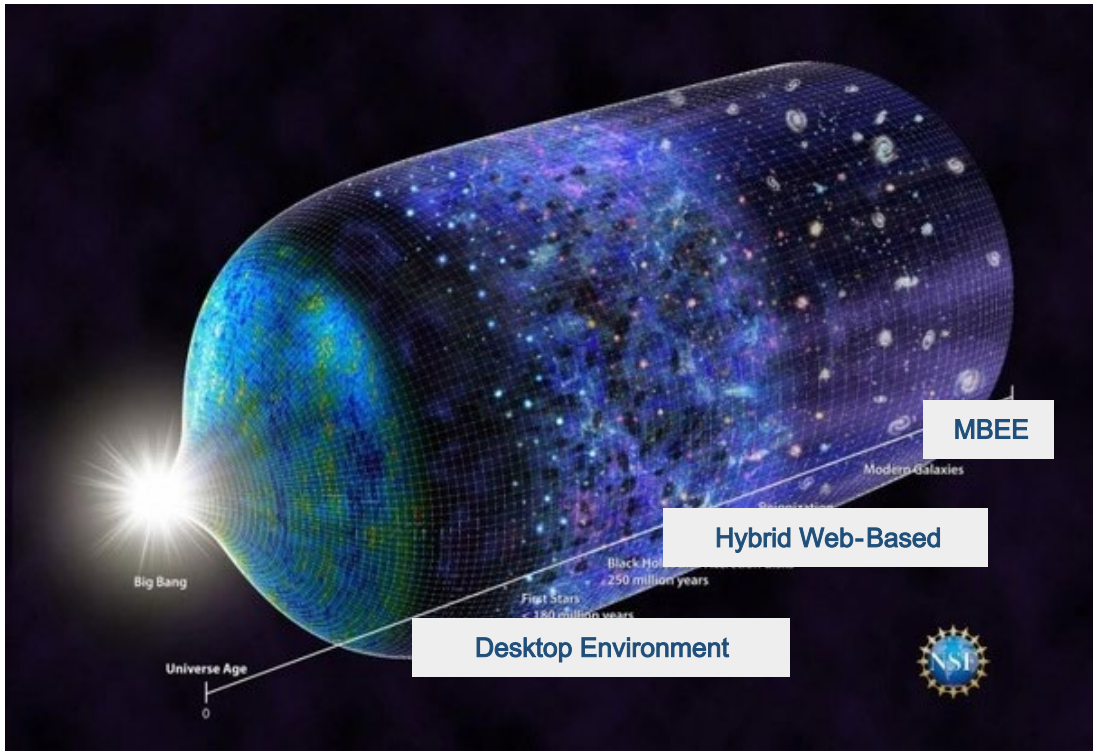
1. Understand how Earth works as a system and how it is changing
2. Help pave the way for human exploration of space
3. Understand how our Solar System formed and how it is evolving
4. Understand how life emerged on Earth and possibly elsewhere in our Solar System
5. Understand the diversity of planetary systems in our Galaxy
6. Understand how the Universe began and how it is evolving
7. Use our unique expertise to benefit the nation and planet Earth

The Rise of the Model-Based Engineering Environments (MBEE)

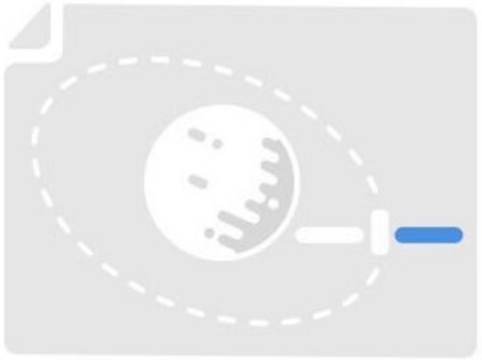
Jet Propulsion Laboratory
California Institute of Technology

MBSE driving MBEE Evolution

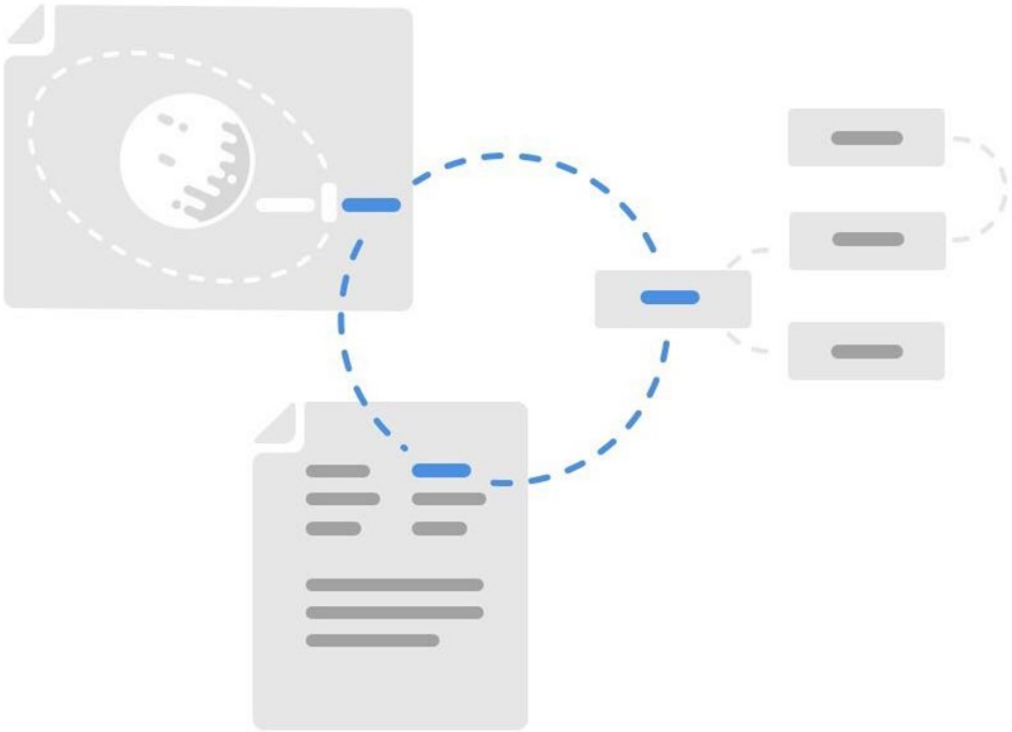
- Shift the value to information
  - Language driven
  - Content driven
- Increase collaboration
  - Culture change
  - Strong compute
- Explicit multi-disciplinary models
  - Web-based
  - So-called digital twins



Precise Engineering Information and Products

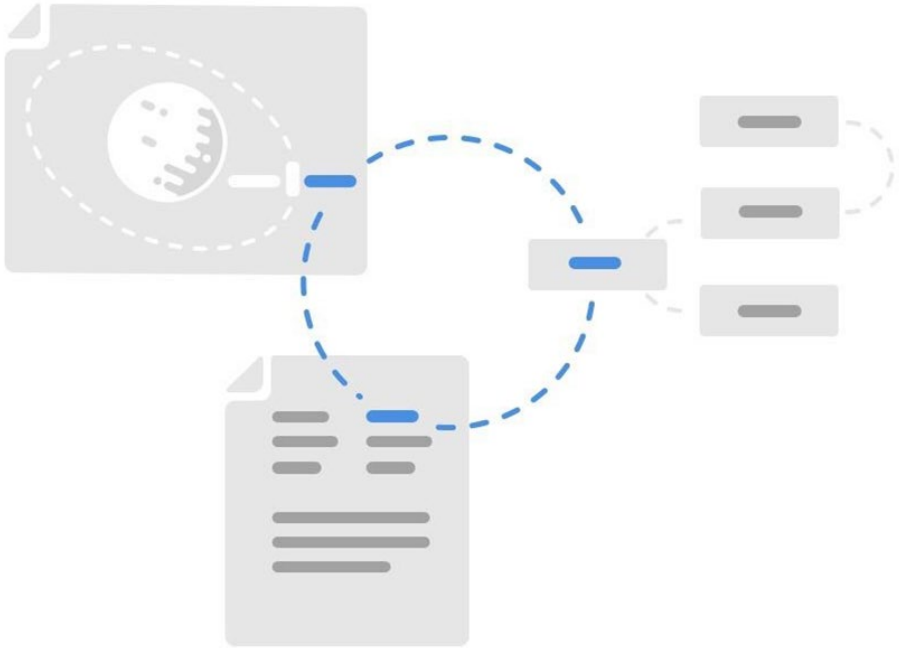


Correspondent Engineering Information and Products

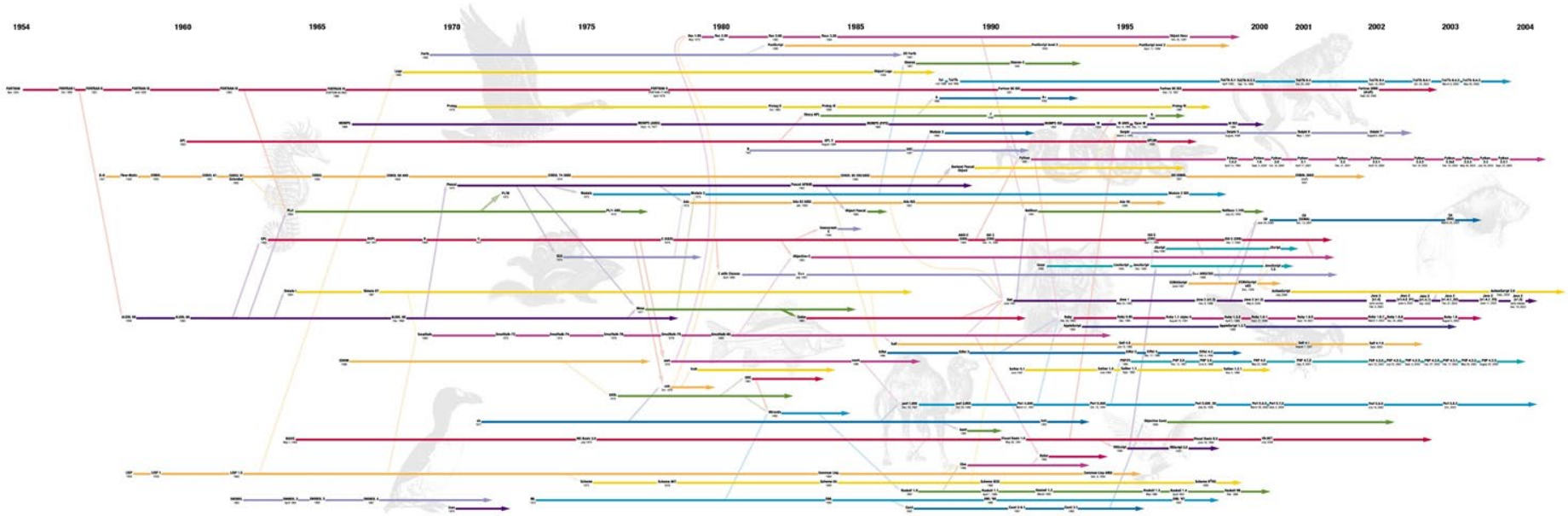


Model Hardening Process

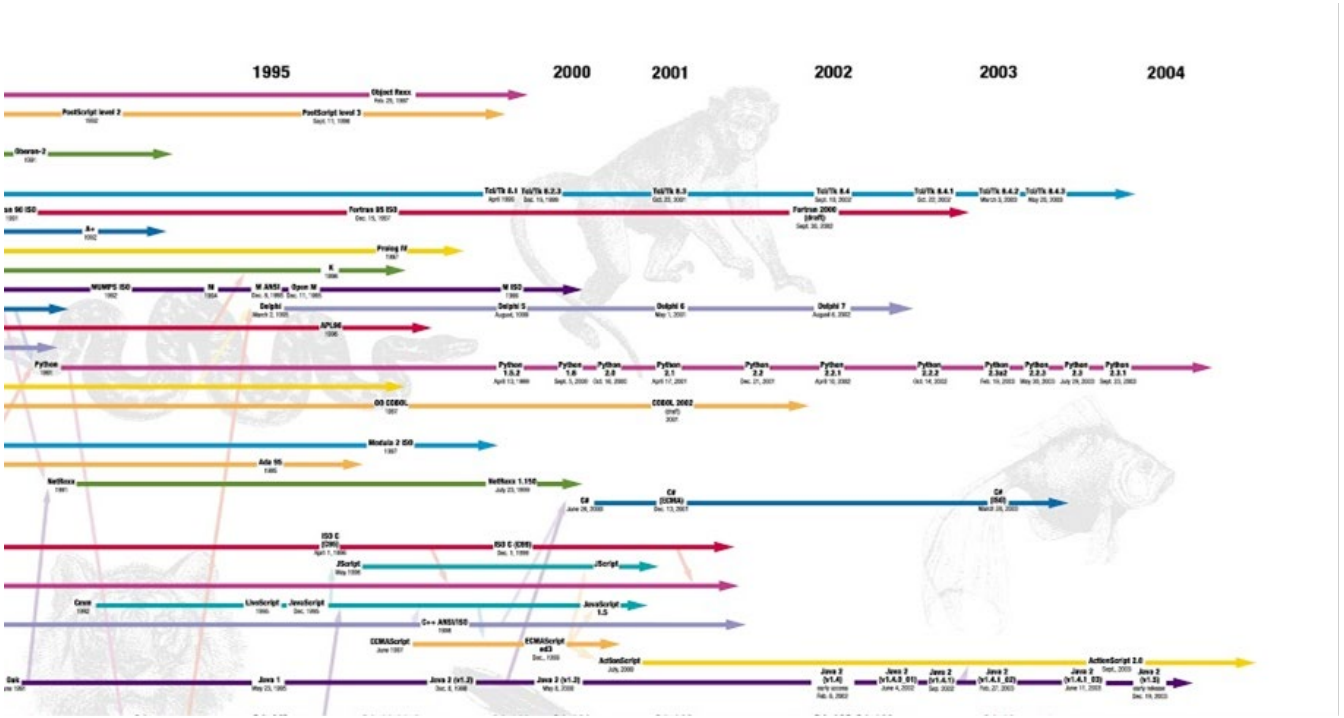
- Where engineering meets project
- Engineering work products are rich and formal but need scope
- Projects start their life cycle with a lot of uncertainty and variation
- How do we use engineering to scope projects and produce systems
- -> Model Hardening
    - Allow the scoped development and merger of project information and engineering models



The Role of Languages in MBEE



The Role of Languages in MBEE



Goal-Oriented Navigation with Google Maps

- Imagine driving a car. As a driver you:
  - Have destinations and deadlines
  - Plan a route
  - Rely on gauges and your own senses

Goal-Oriented Navigation with Google Maps

- By entering a destination into Google Maps:
  - Your requirement is to get from A to B
  - A route is planned based on your location and certain constraints
  - Based on constraints and other information, e.g. traffic, road-work, your location (GPS)
  - You receive directions (Goals) based on constraints and the state of your environment
  - Google Maps is a Goal Planner/Executor/Monitor and the driver a Control System, and the car a System under Control

JPL Model-Based Engineering Environment

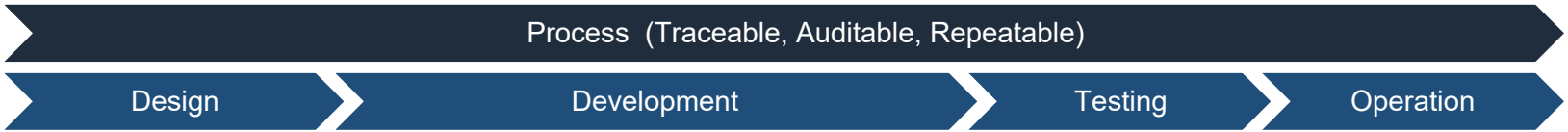
For Systems and Software

Jet Propulsion Laboratory
California Institute of Technology

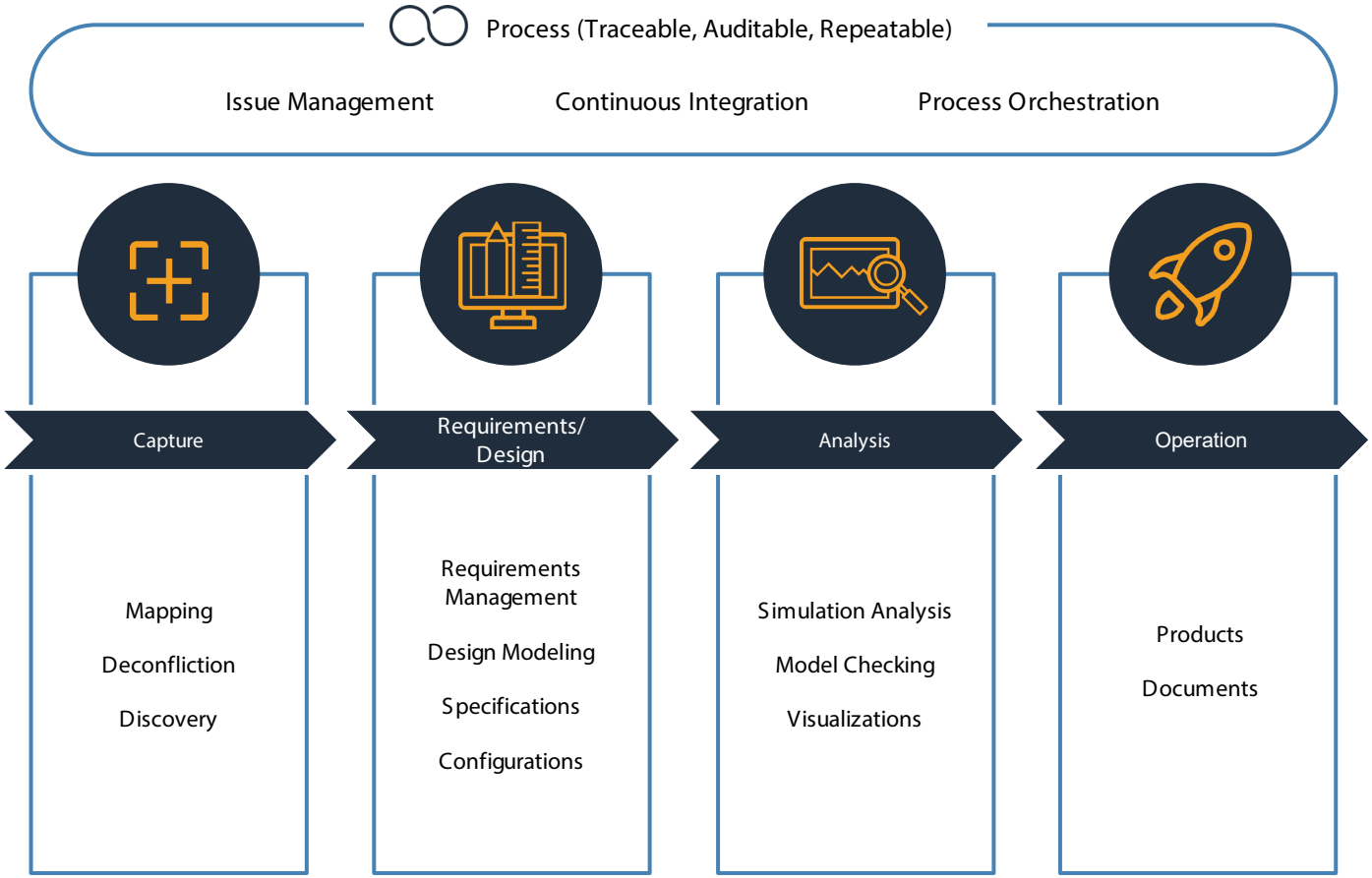
Pipelines

Engineering Pipelines

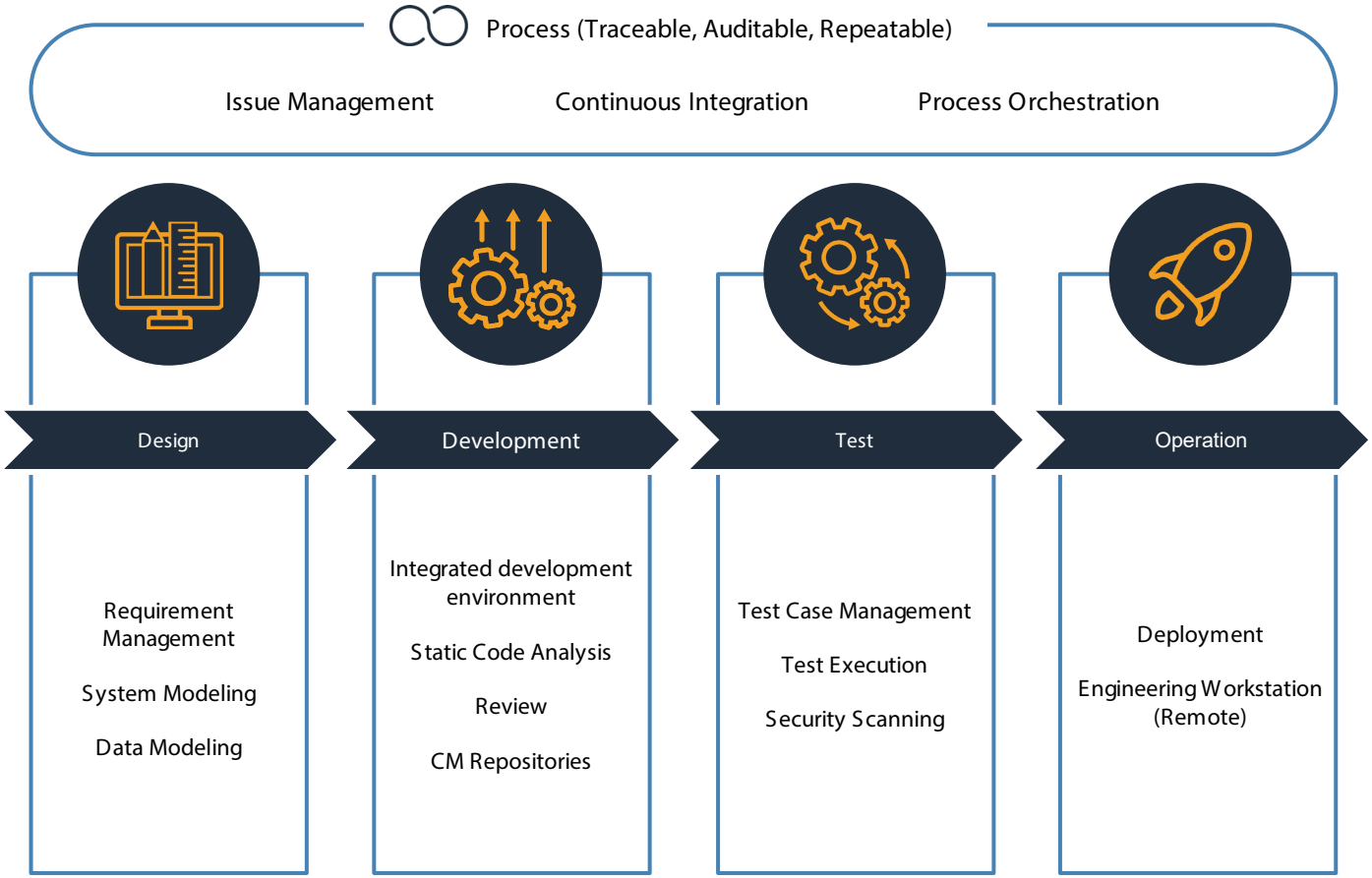
Software Pipelines



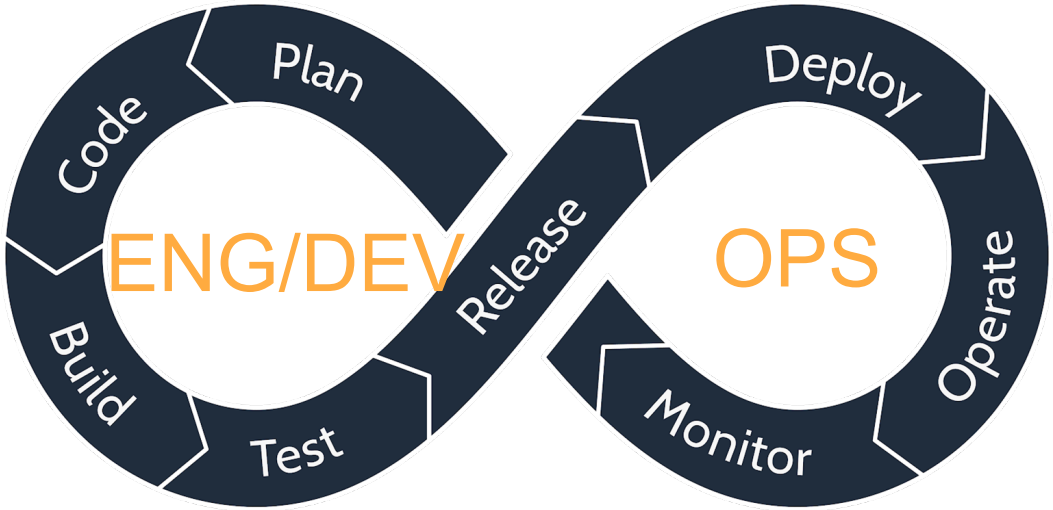
CAE Systems Environment Pipeline - Capability View



Quality Critical Software Pipeline - Capability View



Continuous Engineering Operations



CAE Systems Environment - Technology View

Design | Development | Qualification | Operation

Doors NG
MapleMBE
Figma
Cameo Systems Modeler
oXygen XML Editor
Altova XMLSpy

Pycharm
WebStorm
PhpStorm
CLion
IntelliJ IDEA
Github
Artifactory
X-Ray
Conda
Coverity
Code Sonar
Semmle
lgtm
sonarqube
Smartbear Collaborator
SCRUB
Wind River
Green Hills Software
QP/C
JProfiler

TestRail
Puppeteer
Selenium
AppScan
WSTS

WENG
LENG
jupyter nbviewer
intercax
puppet
Beyond Compare

Process (Traceable, Auditable, Repeatable)

Issue Management
Continuous Integration
Process Orchestration

JIRA
Jenkins
XL Release

Quality Critical Software Environment - Technology View

Design


Doors NG


MapleMBE

Development


Pycharm


WebStorm

PhpStorm


CLion


Github


Artifactory


X-Ray


Conda


Quay


Coverity


Code Sonar


Semmle


Smartbear Collaborator


QP/C

Qualification


TestRail


Robot Framework

?

Operation


WENG


LENG

IDL

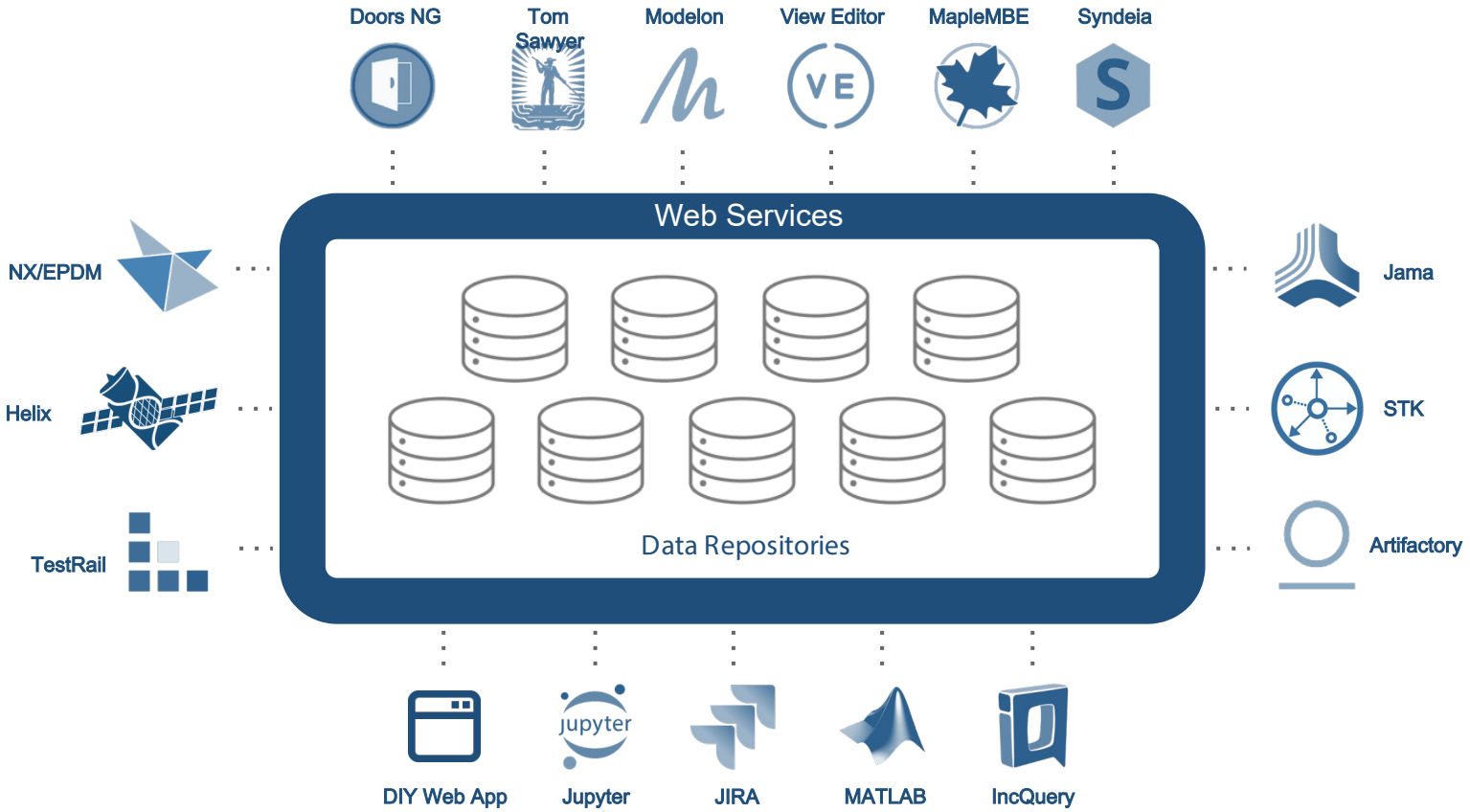

Process (Traceable, Auditable, Repeatable)

Issue Management

Continuous Integration

Process Orchestration

Collaboration with Models



Modeling Languages

Graphical

SysML

UML

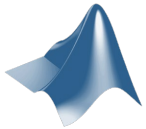
SysML v2

fUML

BPMN

Hybrid Graphical / Text

Modelica



MATLAB

Code / Text

Python

Jupyter

Robot
Framework

Information

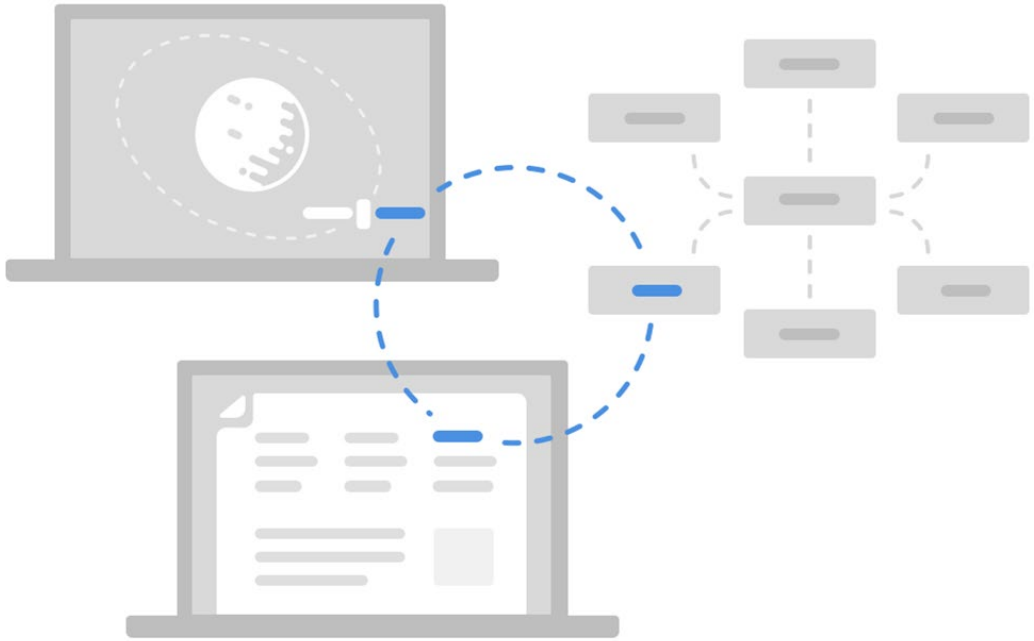
Evolving Cloud Operations

- Over 200 servers, databases
- Over 200 TB of Data
- Full Test String - Development, Test, Integration, User Acceptance, Production
- Managed Services, Software as a Service

Open MBEE Community and Software

Jet Propulsion Laboratory
California Institute of Technology

Open MBEE Community and Software

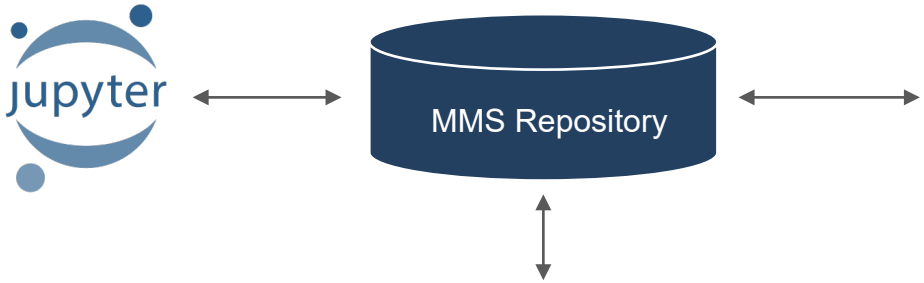


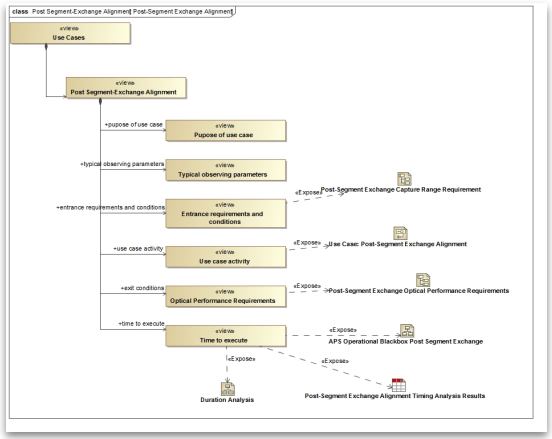
Open Model-Based Engineering Environment

- OpenMBEE is a community for open source modeling software and models
  - Number of open source software activities
  - Number of open source models
- JPL is a participant and adopter of OpenMBEE software and models
- Along with Boeing, Lockheed Martin, OMG, NavAir, Ford, Stevens, Georgia Tech, ESO
- Vendors, practitioners and academia as participants
- ~400 members

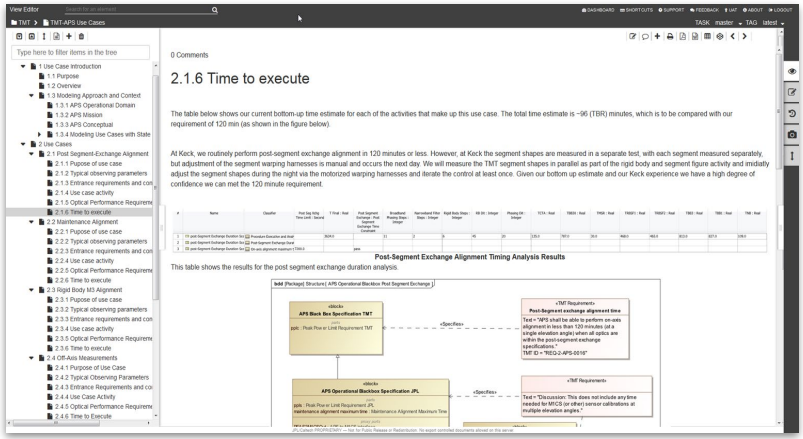
openmbee.org

Linked Data Documents with Open MBEE





Model of Document in MagicDraw / Model Development Kit



Rendered and editable document in Web interface View Editor

OpenMBEE Pipeline

MapleMBSE

View Editor

jupyter

CAMEO SIMULATION TOOLKIT

magicdraw

Github

LGTM

python Package Index

jcenter

JFrog Bintray

docker hub

ANACONDA CLOUD

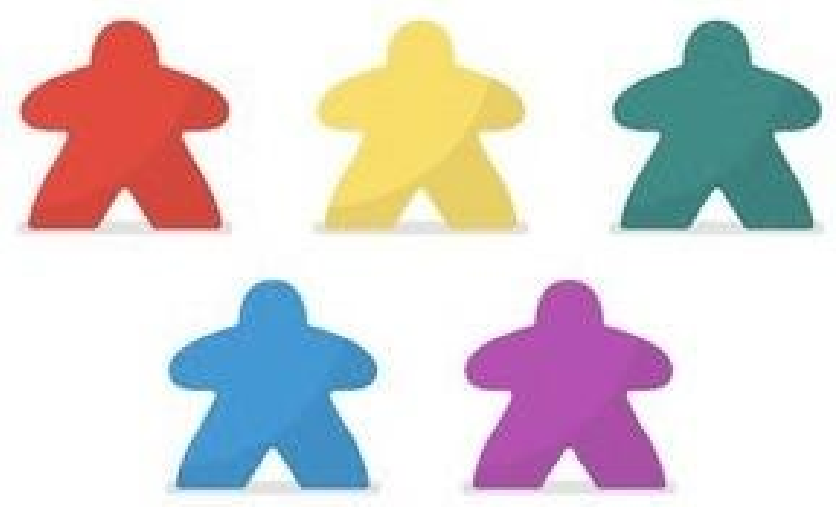
Welcome to the World of Tomorrow

Connected Engineering

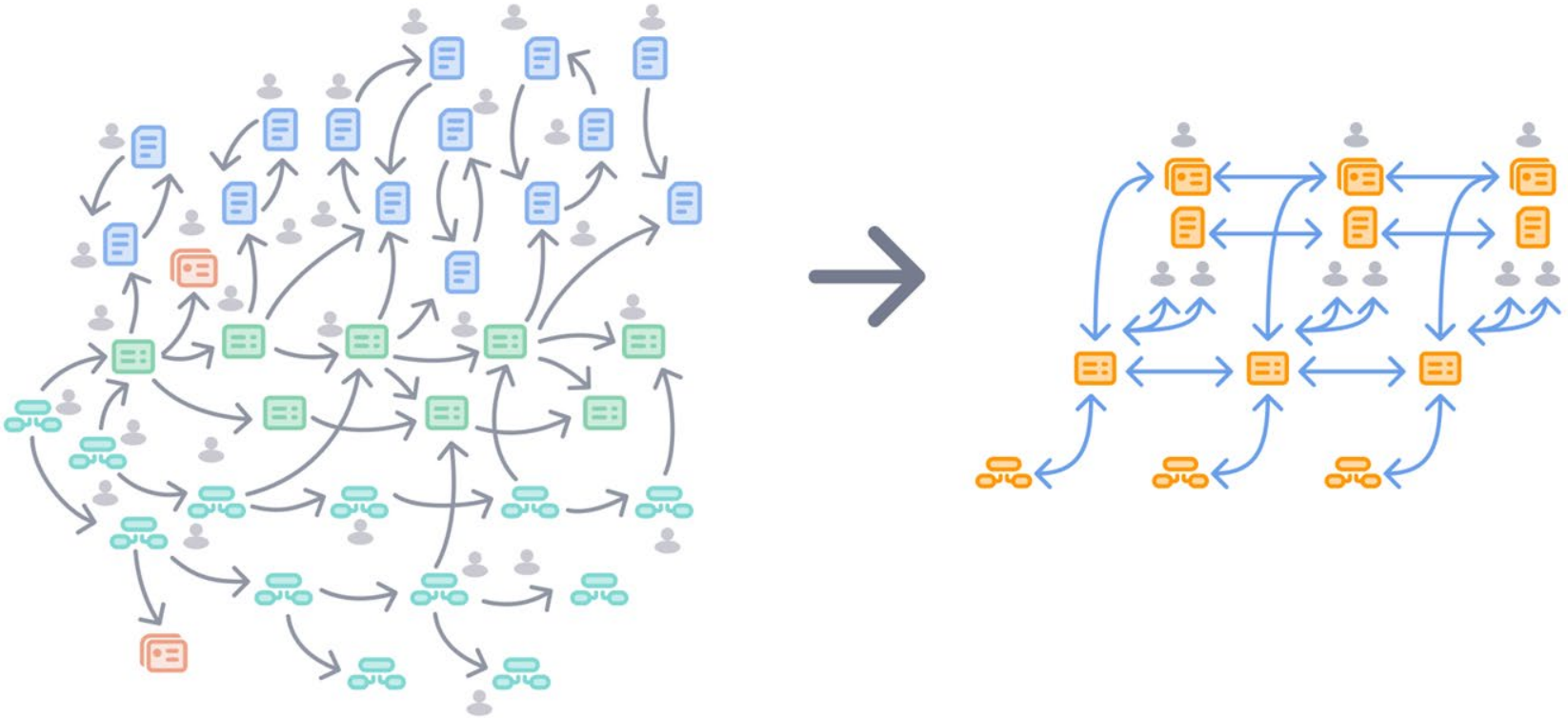
Jet Propulsion Laboratory
California Institute of Technology

Engineers as Humans:
Learning through socially transmitted behavior

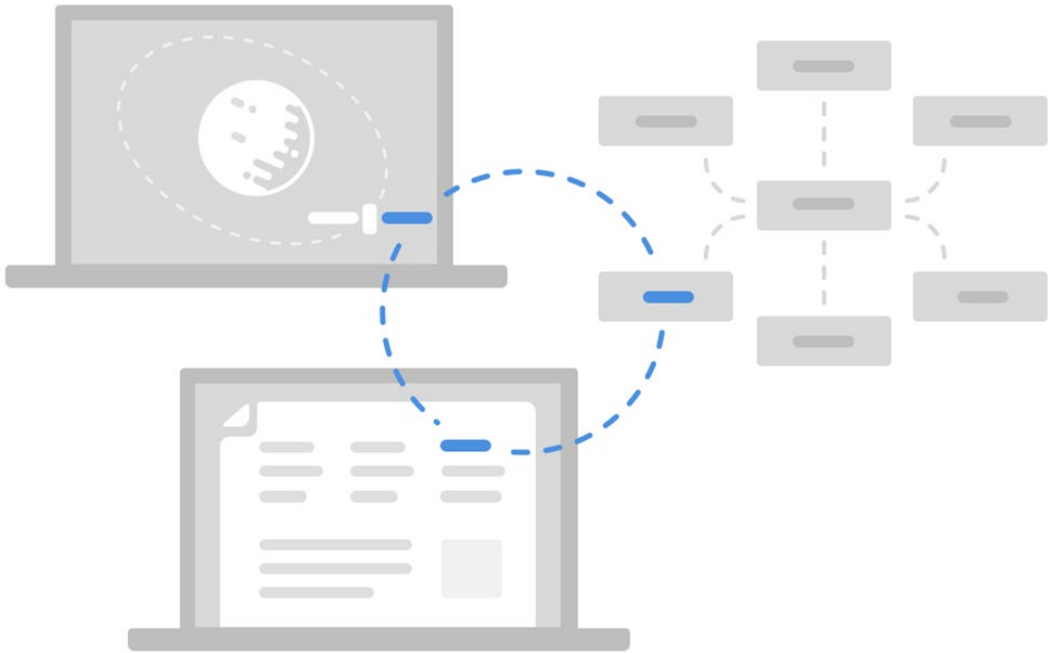
- Disruption of Technical Culture
  - Resistance due to confusion
  - Systemic Process Impact
  - No Users- The Risk of Failure
- Evolving Technical Culture
  - Empathy and Flexibility
  - Human Centered Design
  - Incremental Improvement and Re evaluation



Leveraging Culture to Achieve Transformation

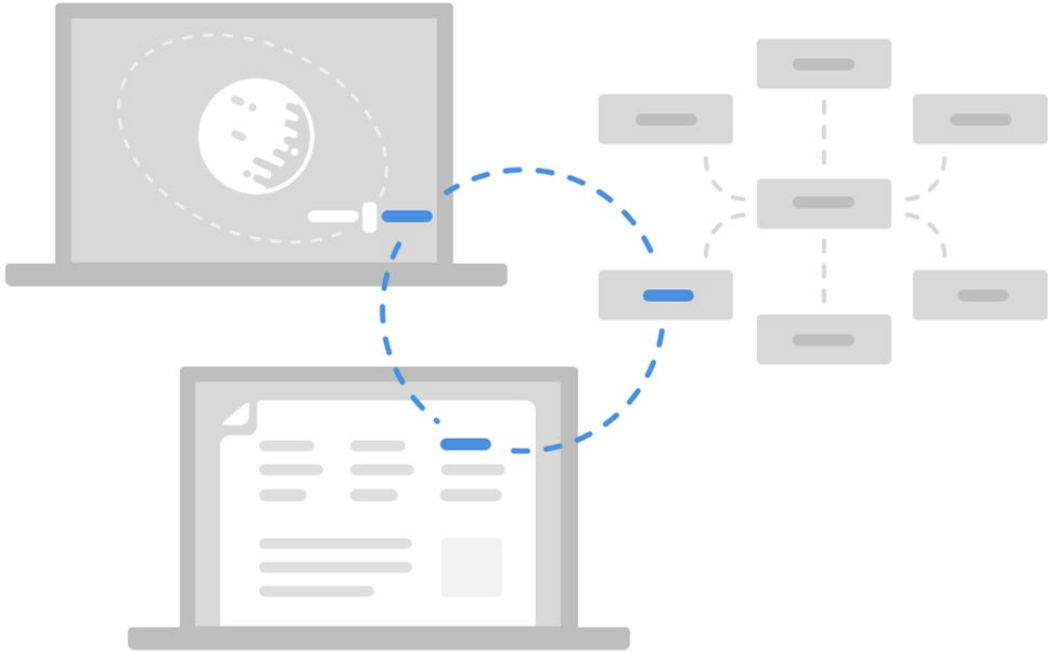


Correspondent Engineering Information and Products



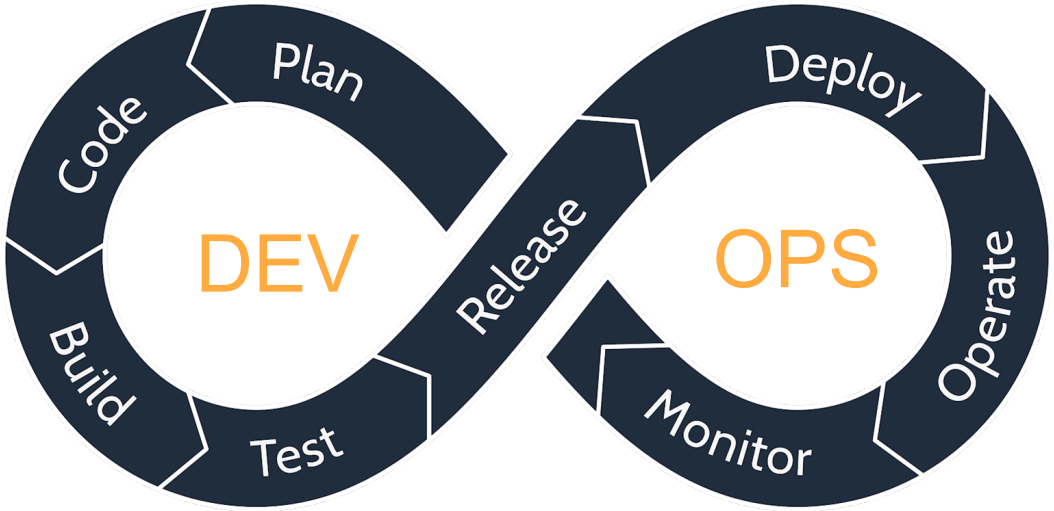
The Significance of Engineering Models

- Unique
- Valuable
- Durable
- Connectable
- Commoditization Unlocks the Value
- Open - Innersource
- Discoverable
- Searchable
- Learnable

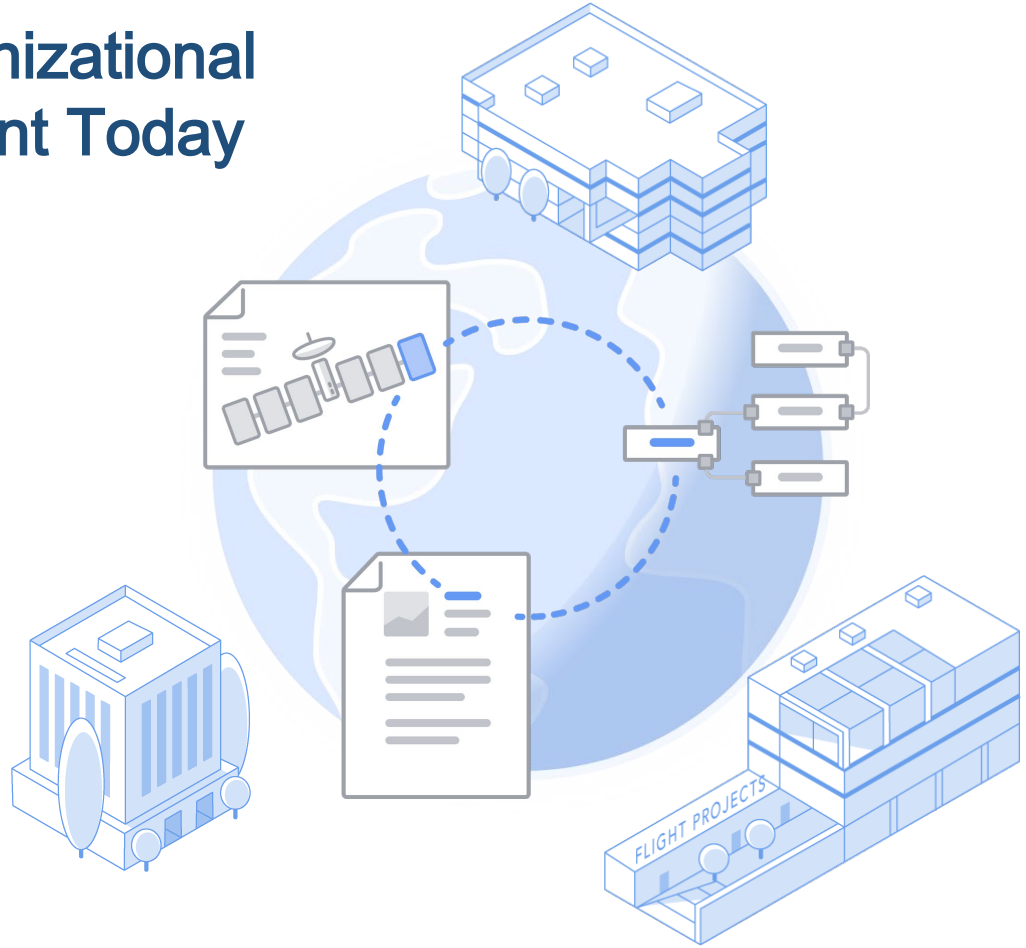


Speed Agility Responsiveness

- Challenges
  - Engineers Consume Software at a significant rate
  - Reliability
- Approach
  - Agility oriented process and methods
  - Serious Computing Only



Intra-Organizational Environment Today



Inter-Organizational Concept

Global Engineering Ecosystem Vision

Connected engineering information
for a connected world

Jet Propulsion Laboratory
California Institute of Technology

jpl.nasa.gov

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- https://www.jpl.nasa.gov/spaceimages/
- Satellite by Made by Made from the Noun Project