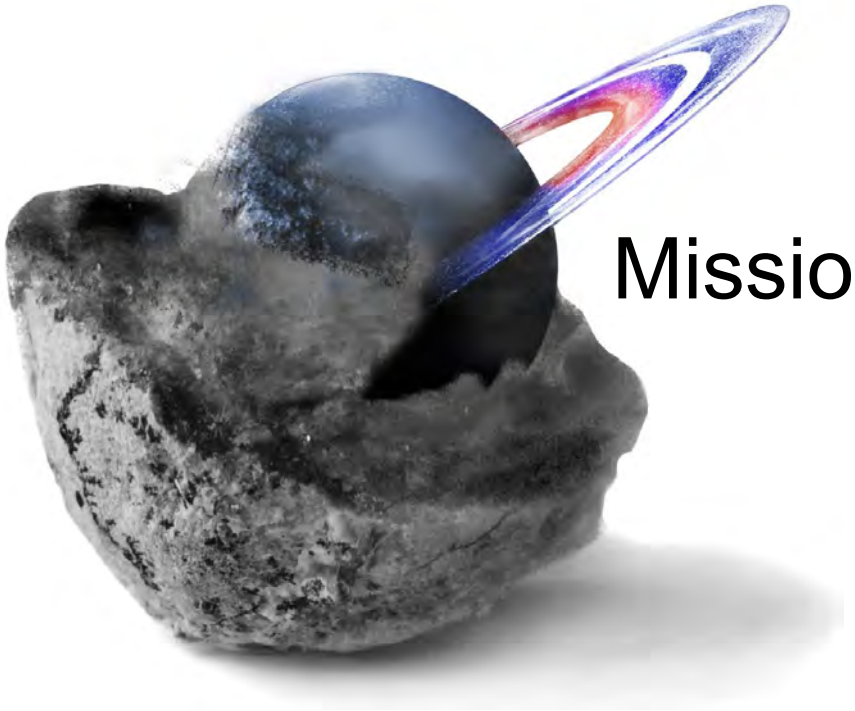

JPL Innovation Foundry

The JPL “A-Team” and Mission Formulation Process

2017 Low-Cost Planetary Missions Conference

Caltech

Pasadena, CA

Steve Matousek, Advanced Concept Methods Manager

JPL's Innovation Foundry

jplfoundry.jpl.nasa.gov

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JPL Innovation Foundry

JPL's Innovation Foundry

jplfoundry.jpl.nasa.gov

- JPL supports the science community to ideate, mature, and propose concepts for new NASA missions
- Continuously "system engineer" requirements and solutions to develop compelling new missions
- The JPL Innovation Foundry is JPL's engine for formulation of exciting, new space mission concepts

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JPL Innovation Foundry

The Foundry Provides

- Method
  - Stable, reliable, clear, understood, exercised
  - Tailored for each stage of the formulation lifecycle
- Smart access to Subject Matter Experts (SMEs)
  - Standout SMEs (technical *and* programmatic)
  - On-demand when (but only when) needed
- Facilities
  - Optimized for pace and interactions of formulation
- Smart access to prior work
  - Thousands of engineered concepts, hundreds of vetted proposals, tens of PI-led missions already “in the can”
- Hands-on coaching of the formulation craft

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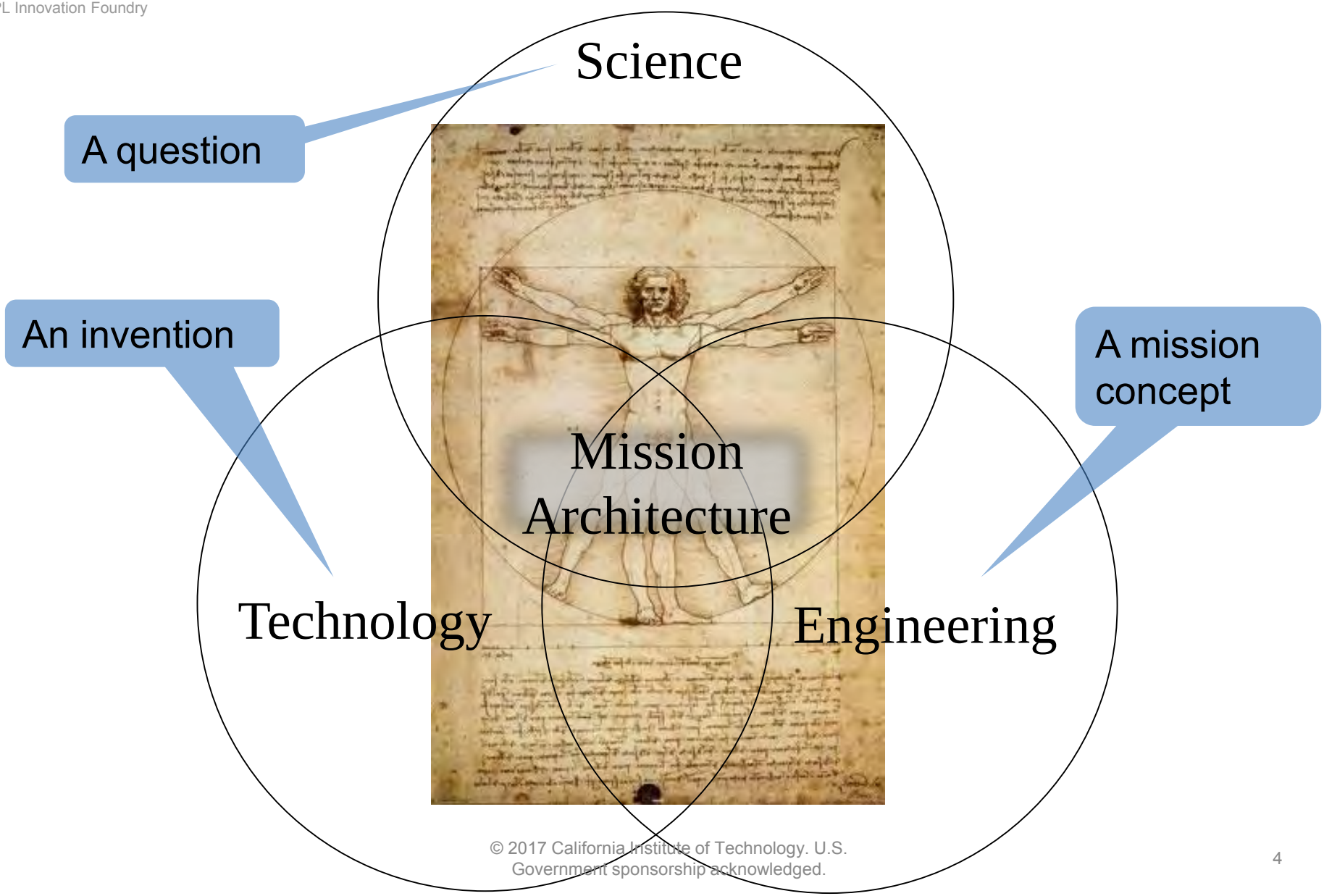
Every mission starts with a spark



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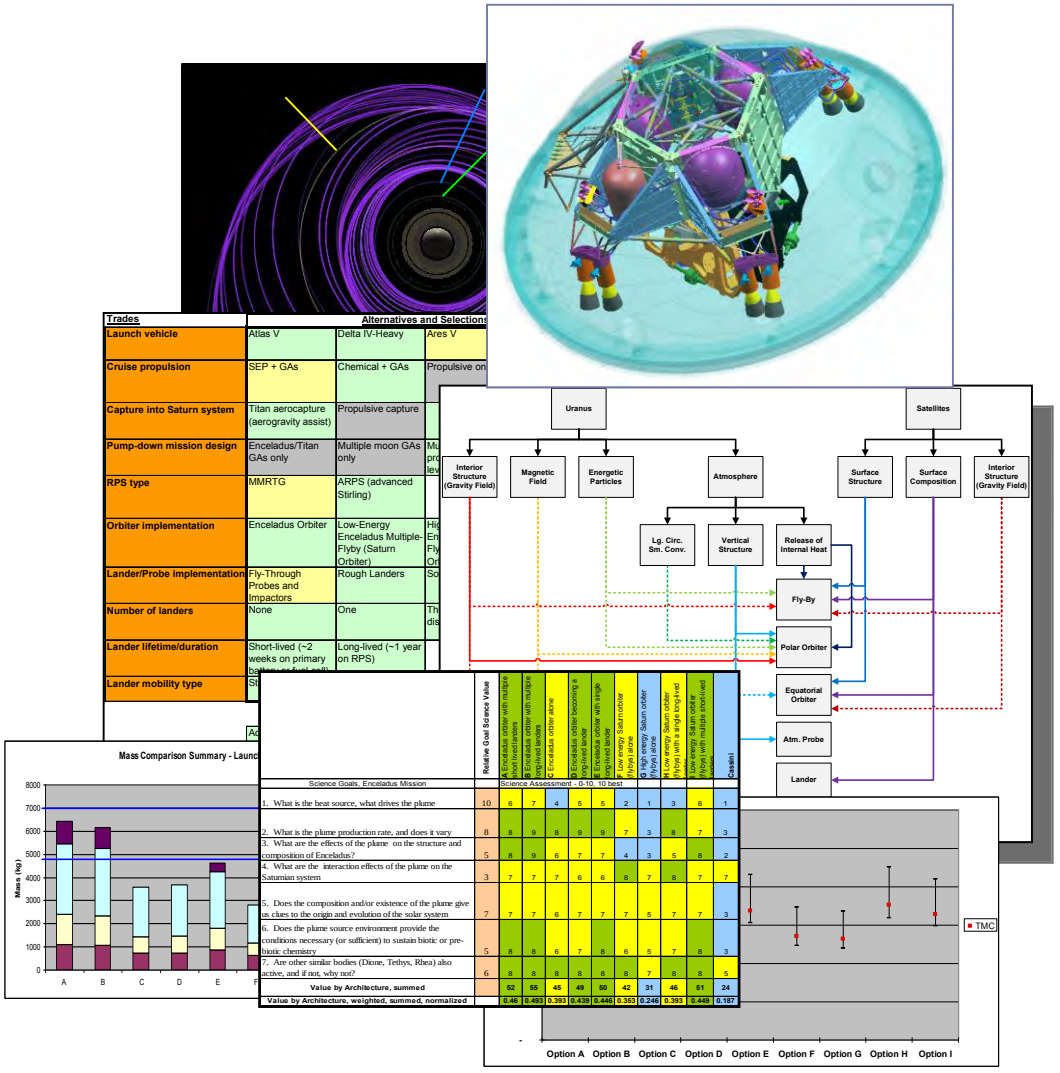
…then the concept is developed

or



One person's concept is another's doodle…

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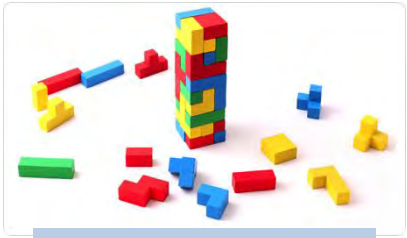
The Foundry Infrastructure

JPL Innovation Foundry

Study Management

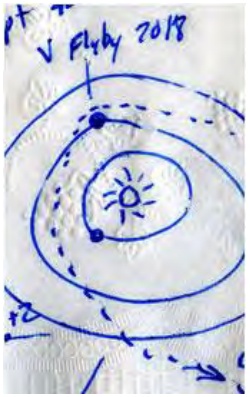
Stand-alone Databases

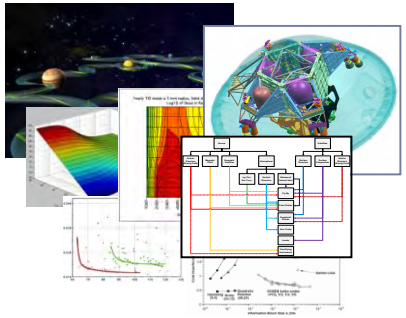
Model Repository



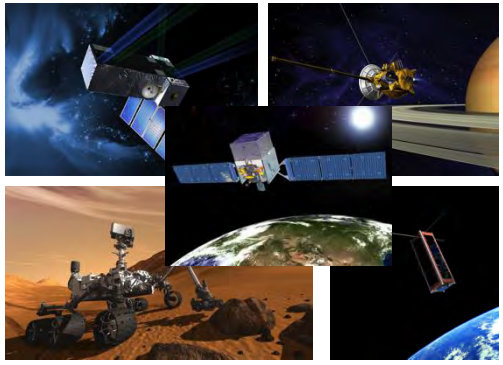
Model Construction & Execution Environment

Execution Engine





Concept Maturity Level



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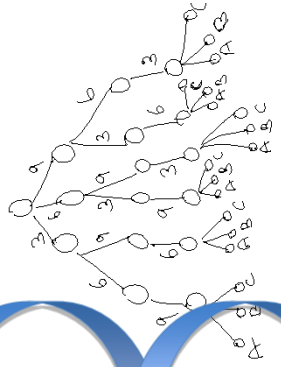
CMLs: A Powerful Communication Tool

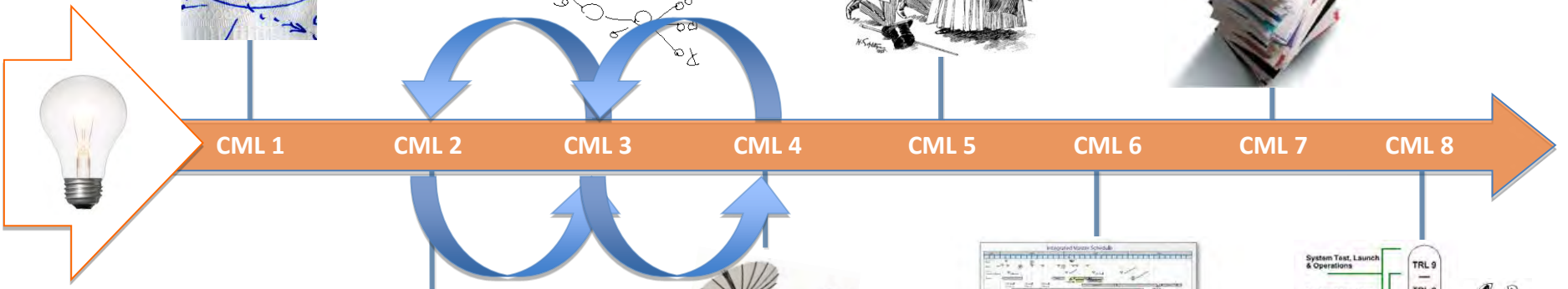
Cocktail Napkin

Trade Space



Baseline Concept

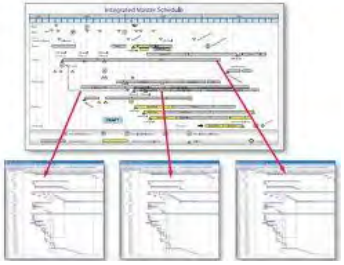
Preliminary Implementation Baseline



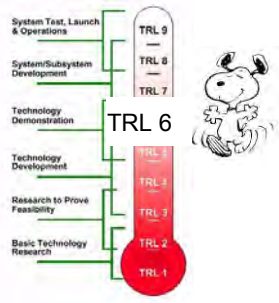
F = m a

Initial Feasibility

Point Design



Integrated Concept



Integrated Baseline

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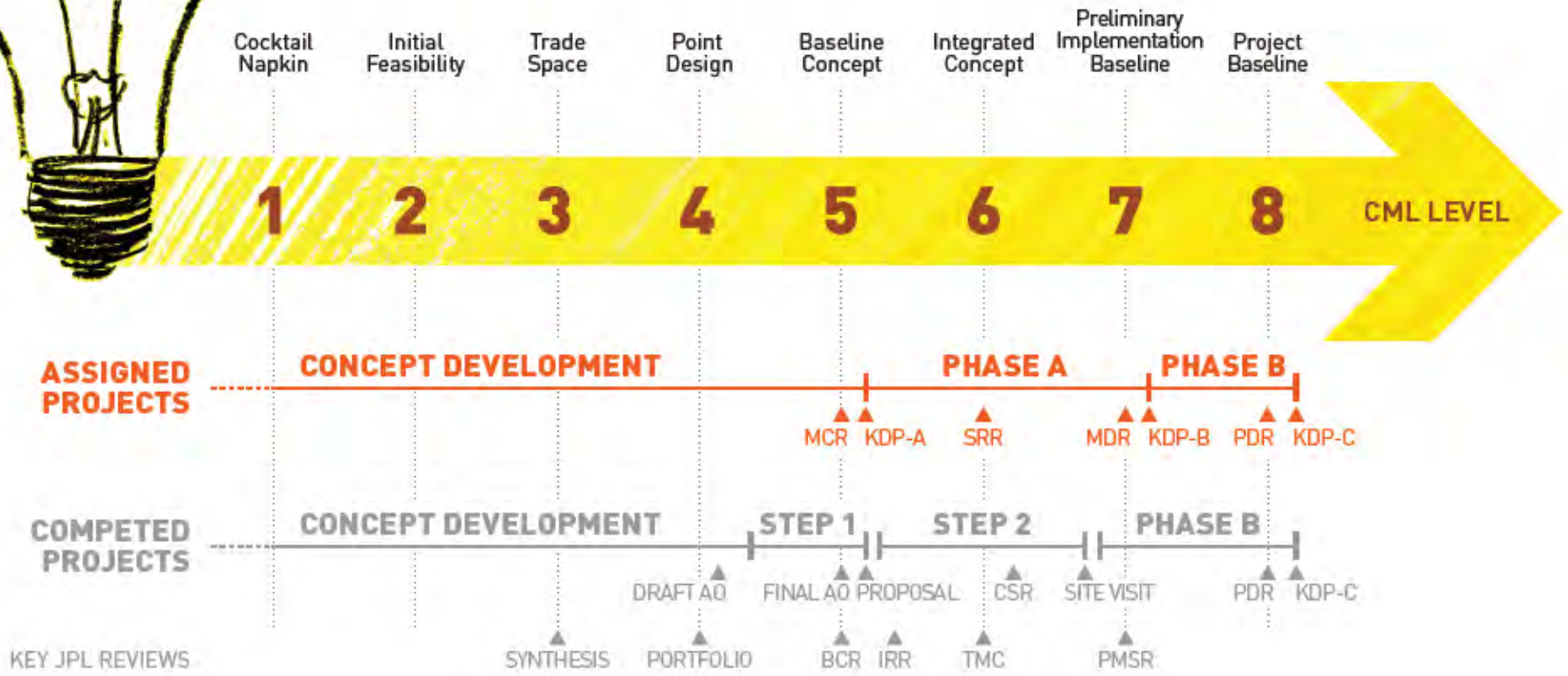
CONCEPT MATURITY LEVELS (CML)

for NASA Competed and Assigned Projects



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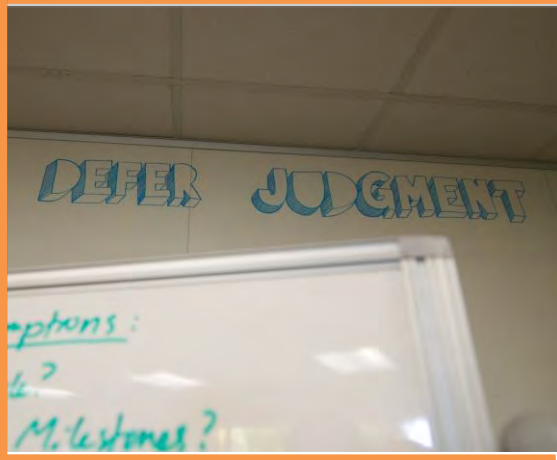
F=ma

Client Supplied Materials
Archive

LEFT
FIELD


DEFER JUDGMENT

F=ma

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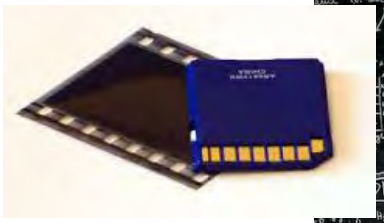
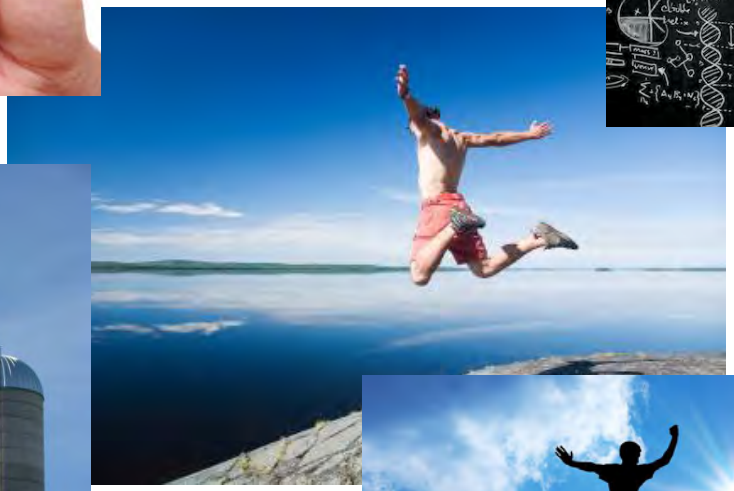
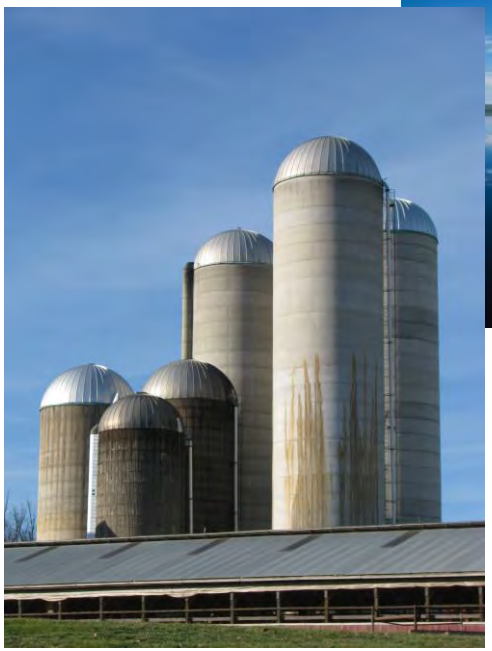
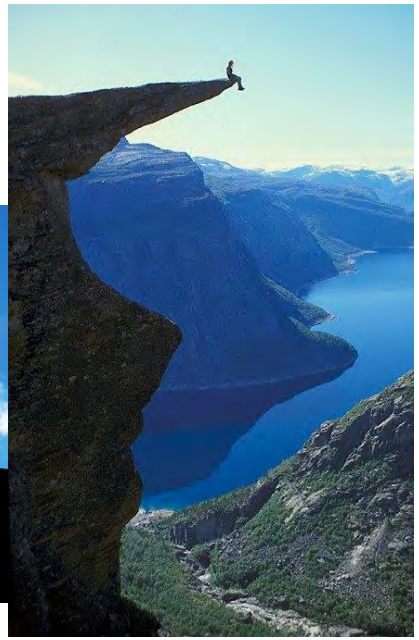
Early Concept Challenges









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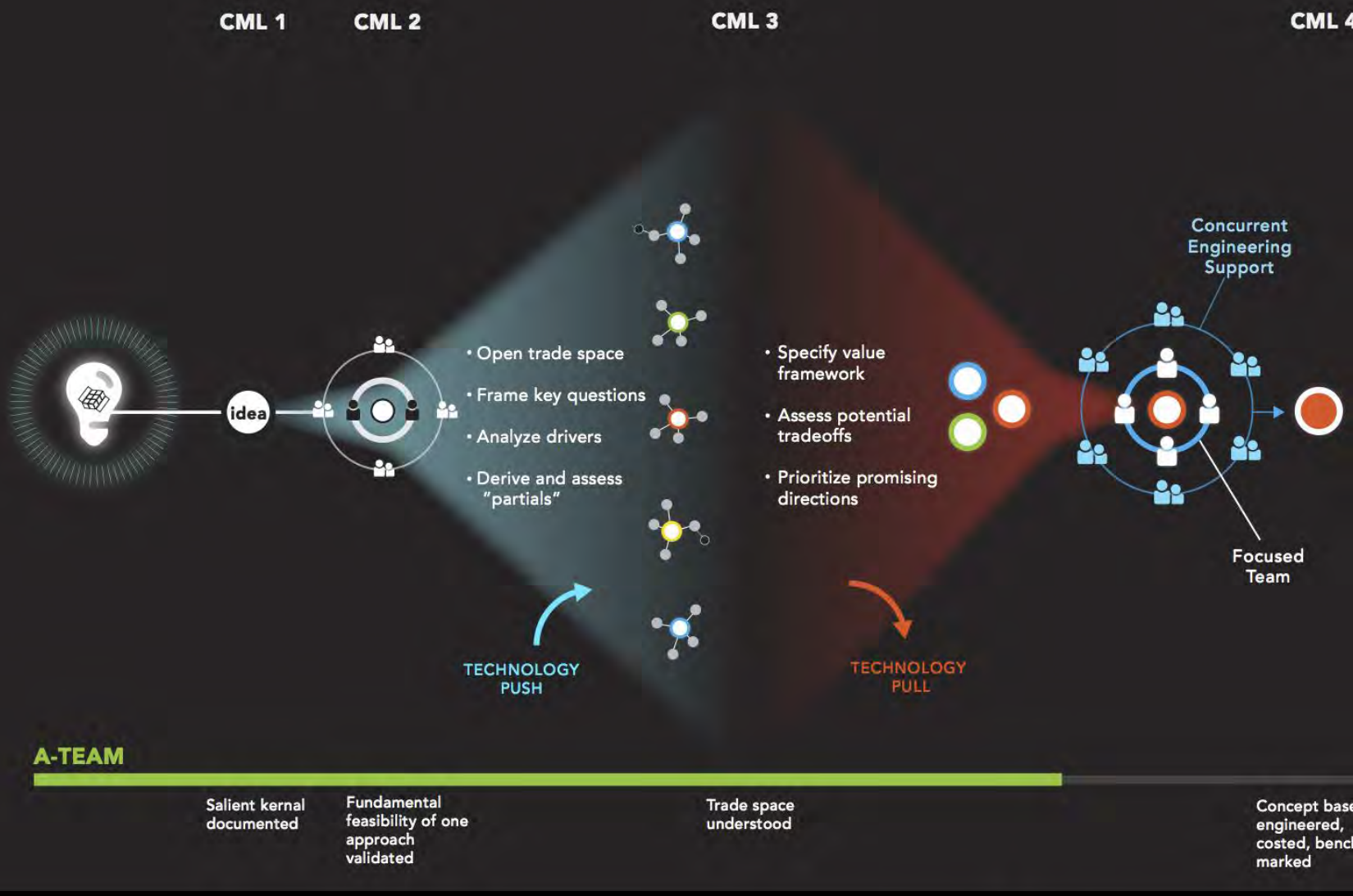
CML 1
CML 2
CML 3
CML 4
idea
• Open trade space
• Frame key questions
• Analyze drivers
• Derive and assess "partials"
• Specify value framework
• Assess potential tradeoffs
• Prioritize promising directions
Concurrent Engineering Support
Focused Team
TECHNOLOGY PUSH
TECHNOLOGY PULL
A-TEAM
Salient kernal documented
Fundamental feasibility of one approach validated
Trade space understood
Concept baseline engineered, costed, bench-marked
LEGEND:
IDEA
CONCEPT PROTOTYPE
POINT DESIGN

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The A-Team

A guided conversation with set objectives and proven methods

A early focal point for concept teams to build and mature ideas

A network of experts, leaders, and innovators

A center for intellectual honesty and exploration

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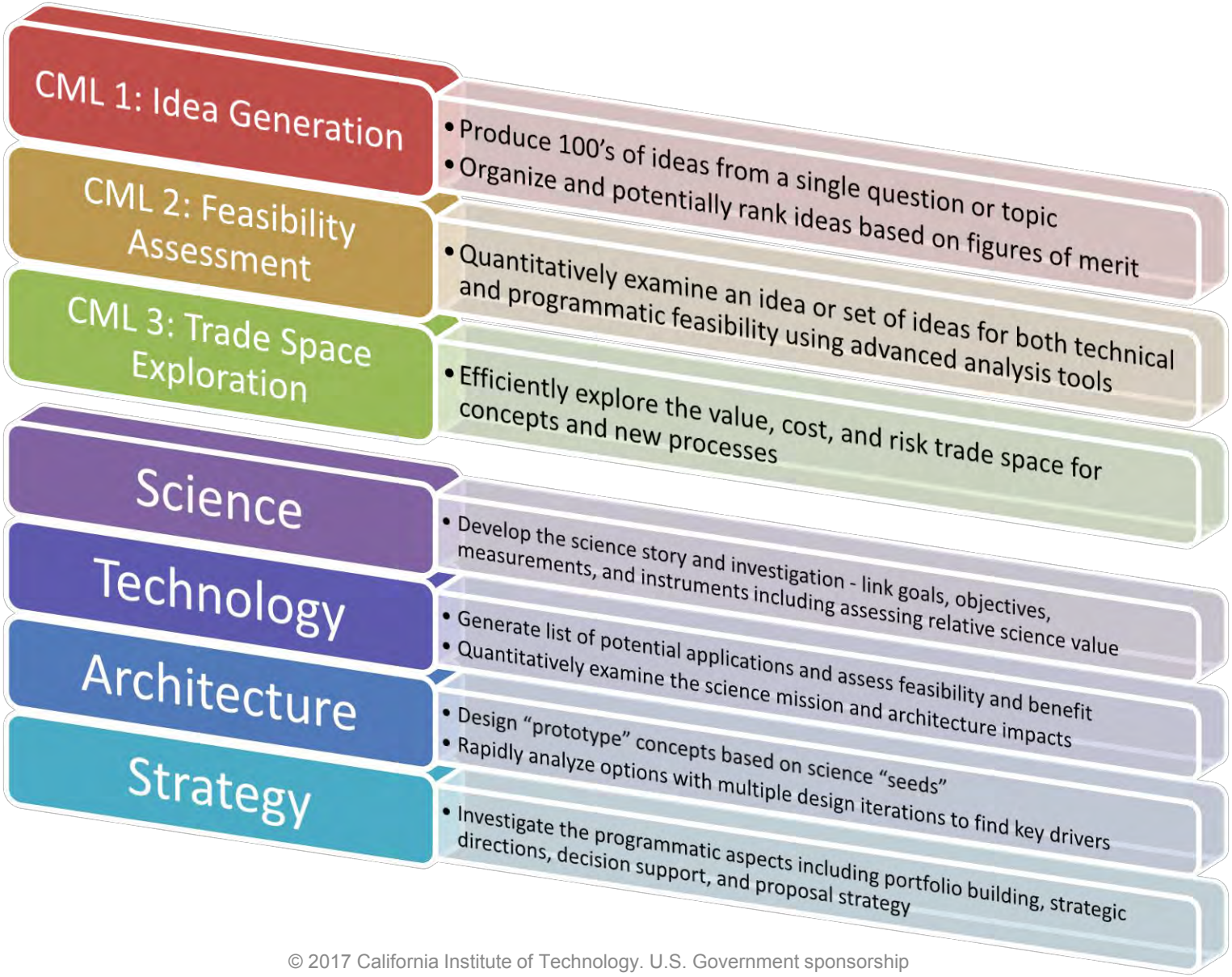
A-Team Study Types



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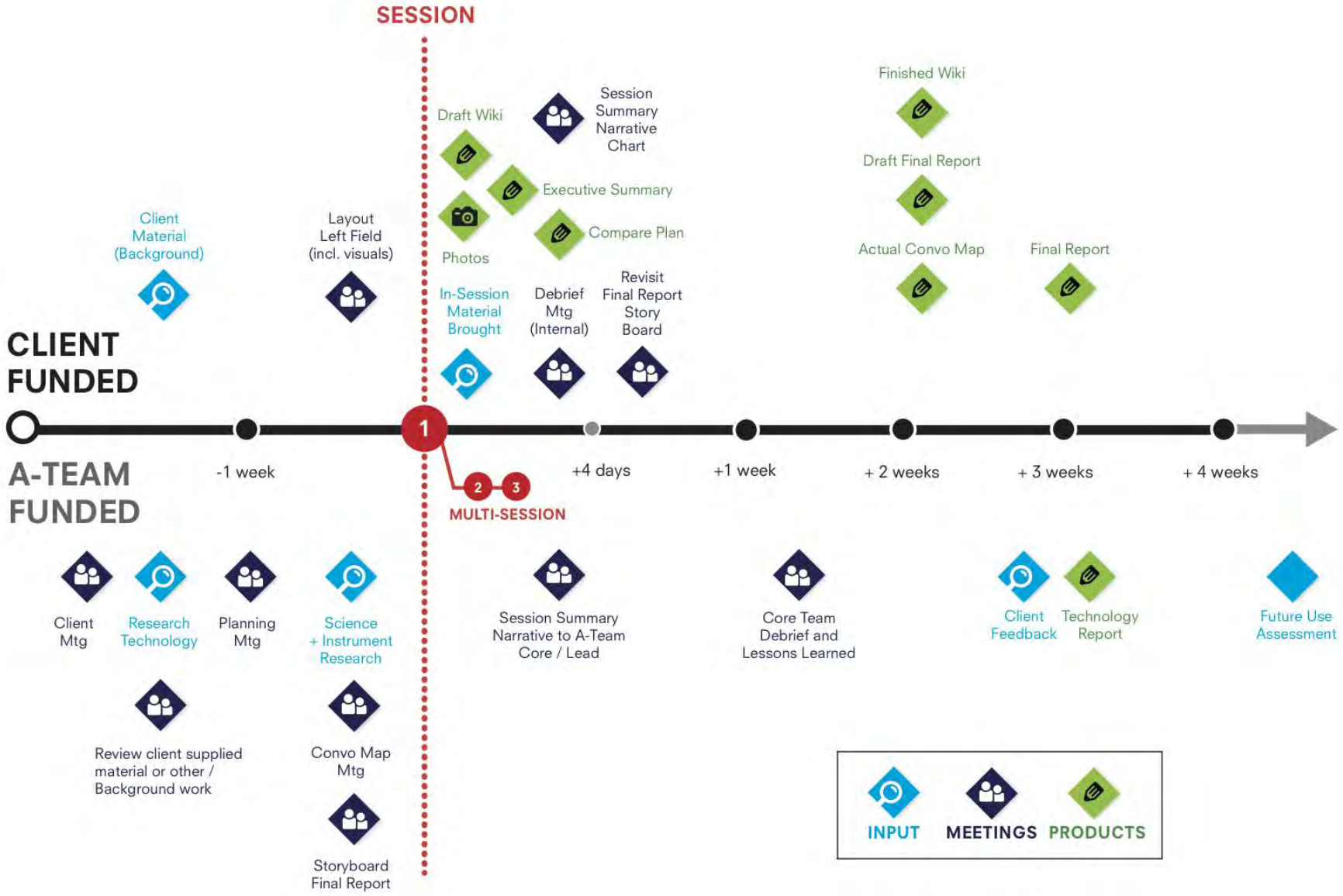
A-Team Study Timeline



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A-Team Study Types and Statistics From Over 200 Studies

Idea Generation

67% of studies included CML 1

Only 24% of studies ended at CML 1

Feasibility Assessment

76% of studies included CML 2

Most studies, 51% ended at CML 2

Trade Space Exploration

25% of studies included CML 3

9% of studies went to Team X

Science

Primary focus for 37% of studies

Secondary focus for 13% of studies

Technology

Primary focus for 25% of studies

Secondary focus for 20% of studies

Architecture

Primary focus for 28% of studies

Secondary focus for 25% of studies

Strategy

Primary focus for 10% of studies

Secondary focus for 42% of studies

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A-Team Study Types and Examples

Idea Generation
- 3D Printing at JPL
- Venera-D NASA Contribution

Feasibility Assessment
- Deep-Space Relay via CubeSat (MarCO)
- Planetary Science from Atmospheric Balloons

Trade Space Exploration
- Ultra Low-Cost Planetary Missions
- Ionospheric Magnetospheric Constellation Concept

Science
- Venus In-Situ Science Return
- Using Smallsats for Earth Science Missions

Technology
- Origami Workshop
- In-Space Propulsion for Mars Sample Return

Architecture
- Low cost Venus exporation
- DSN Follow the Sun Program Architecture

Strategy
- Storytelling
- Exploring Future Spacecraft and Science Missions

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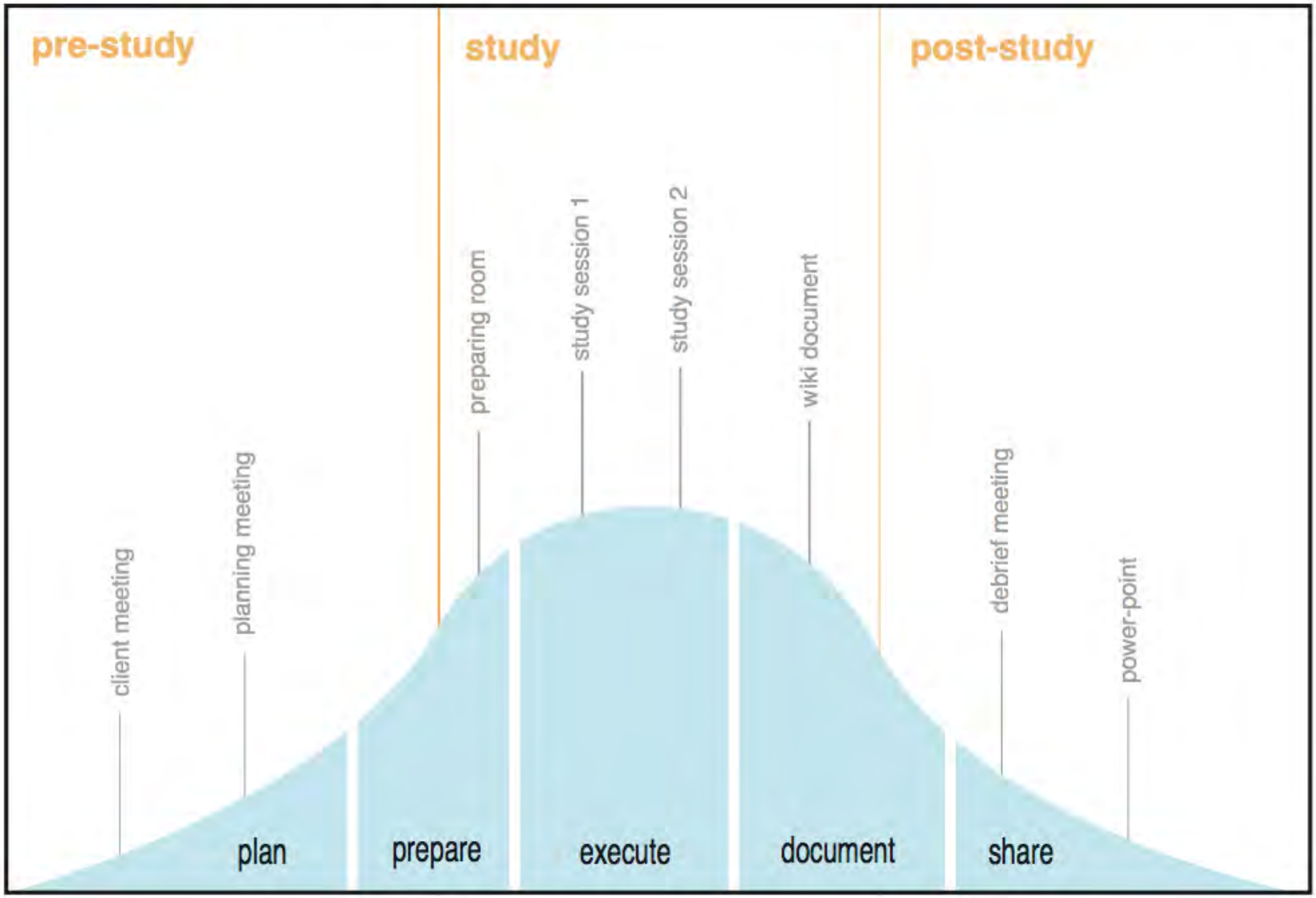
A-Team Process Overview



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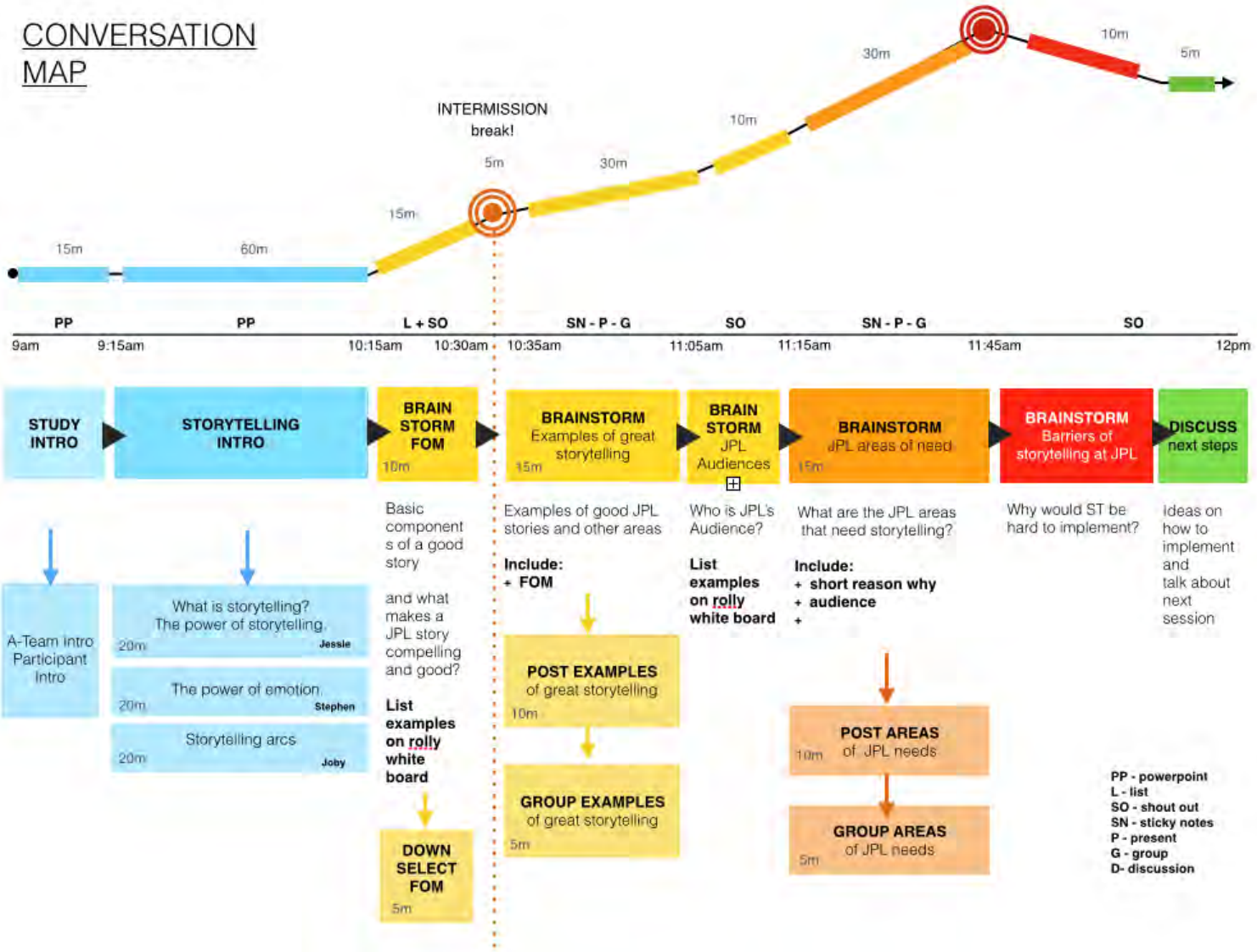
Example: Planning a Session



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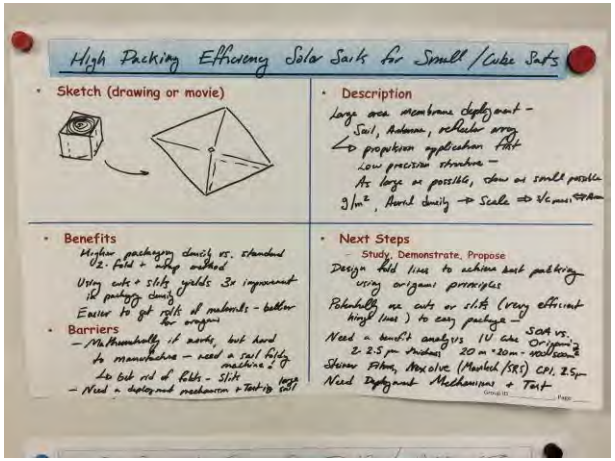
Example Study: Origami in Space



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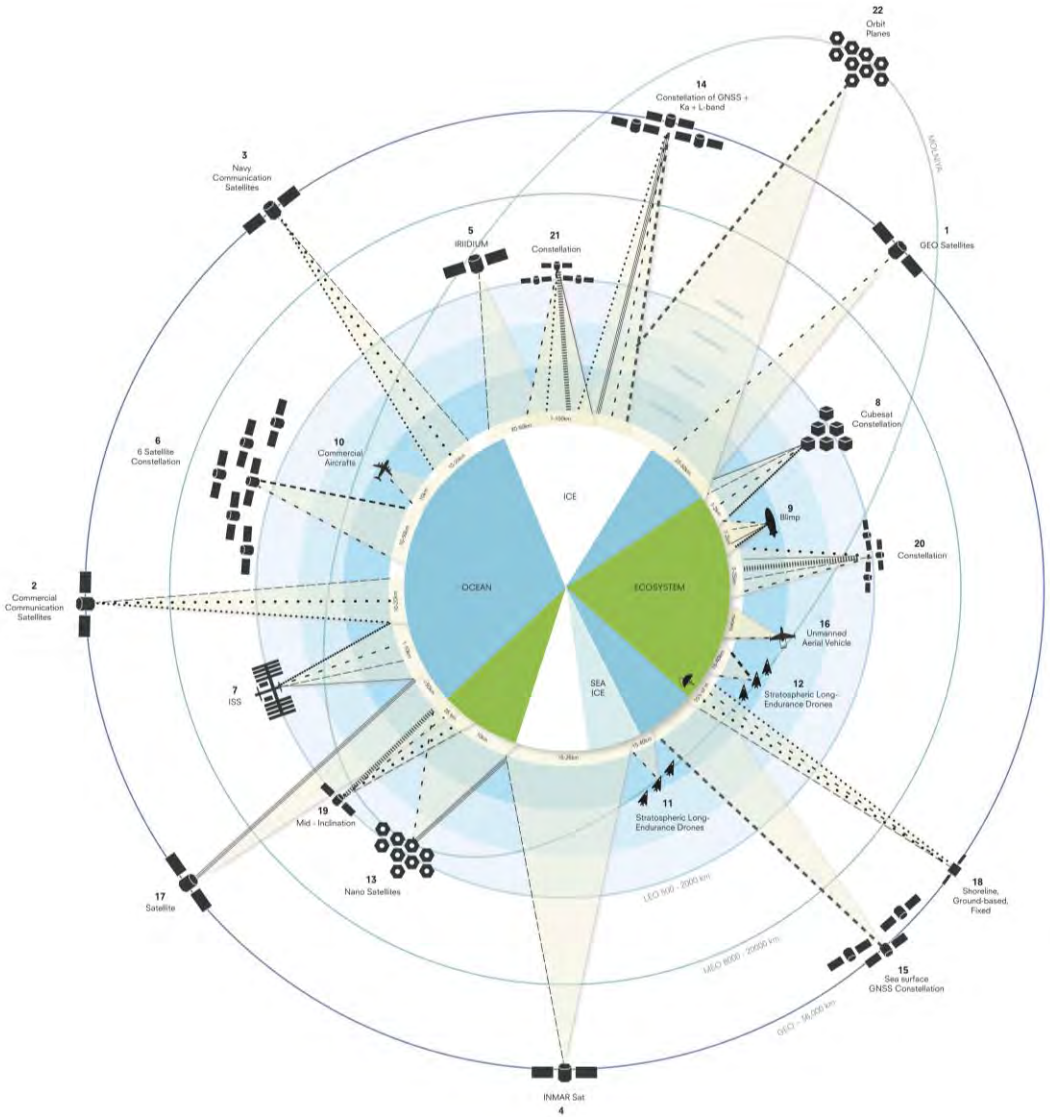
Design Thinking and Visual Strategy

PLATFORM

1 GEO SATELLITES
2 COMMERCIAL COMM SATELITTES
3 NAVY COMM SATELLITES
4 INMAR SAT
5 IRIDIUM
6 STATIONARY SITE
7 SATELLITE CONSTELLATION
8 ISS
9 CUBESAT CONSTELLATION
10 COMMERCIAL AIRCRAFTS
11 STRATOSPHERIC LONG-ENDURANCE DRONES
12 STRATOSPHERIC LONG-ENDURANCE DRONES
13 NANOSATELLITES
14 CONSTELLATION OF GNSS+Ka+L-BAND
15 SEA SURFACE GNSS CONSTELLATION
16 UNMANNED AERIAL VEHICLE
17 SATELLITE
18 SHORELINE, GROUND-BASED, FIXED
19 MID-INCLINATION
20 LEO CONSTELLATION
21 LEO CONSTELLATION
22 ORBIT PLANES

WAVELENGTHS

K-band
Ka-band
Ku-band
L-band
S-band
X-band
C-band
GNSS
Multiple



ICONS

Satellites
Cubesats
Nanosats
Drones
International Space Station
Blimp
Commercial Aircraft
Unmanned Aerial Vehicle
Direct Broadcast Dish
Public and Private Satellites

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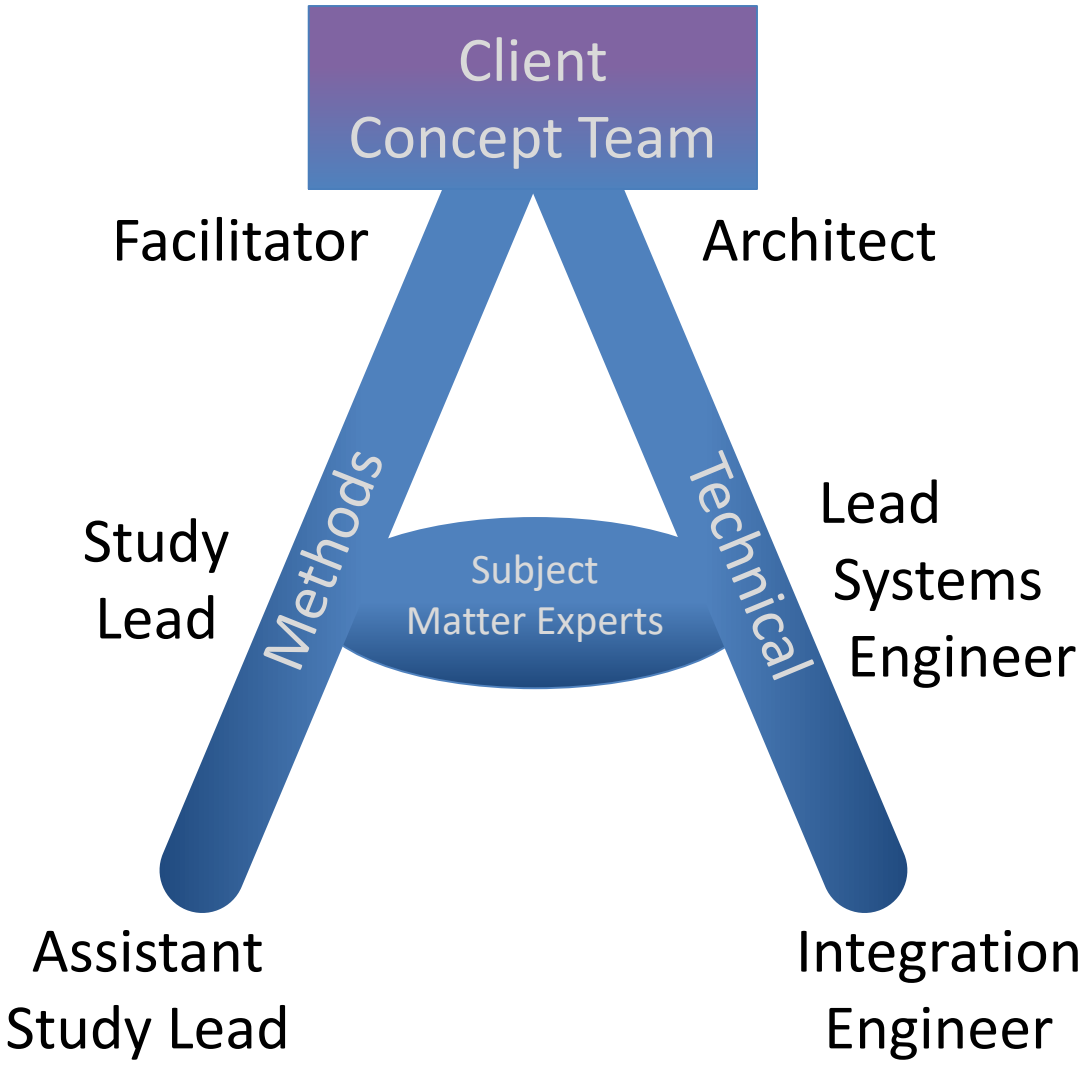
The “A-Frame”



- Each A-Team study has a 3-6 person “A-Frame Team” from two points of view:
  - Innovative Methods
  - Technical Expertise
- Additional subject matter experts are brought in as needed (customized)
- The client may also add members from the Concept Team

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The A-Team Core

- The A-Team core is a set group of leaders to build best practices and expertise in the following areas:
  - Facilitation
  - Study Leadership
  - Knowledge Capture
  - Design Thinking
  - Tools and Infrastructure
  - Science
  - Instruments: Remote Sensing, In Situ, and Radar
  - Mission Design
  - Flight Systems and Architecture
  - Configuration
  - Technology
  - Cost and Risk
  - Data Science

- Positions are inherently rotational (1-3 year time frame)
- This group also leads the bulk of our studies

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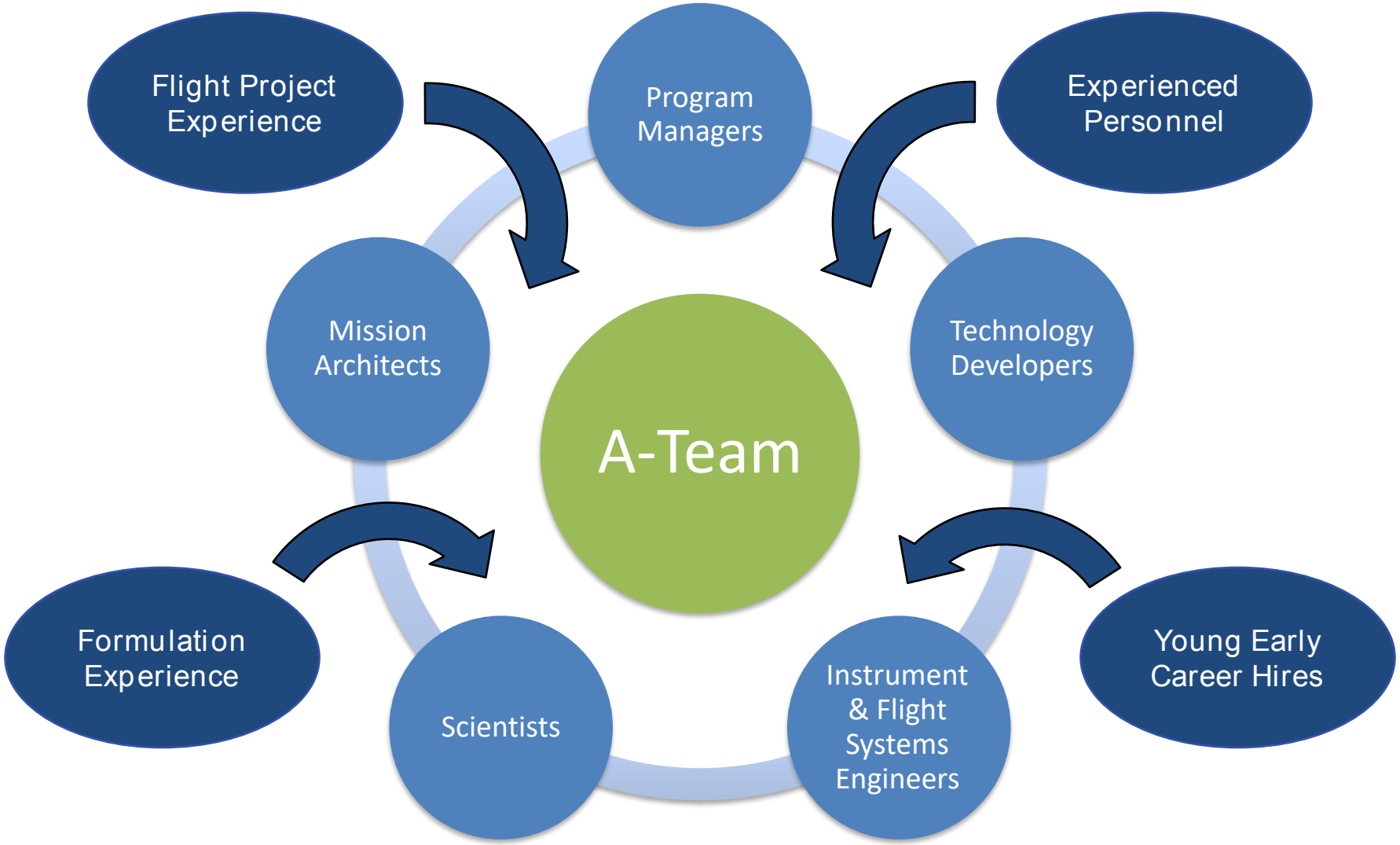
Key Aspect to A-Team Innovation: People



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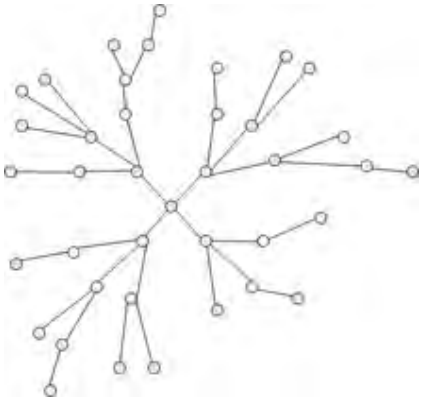
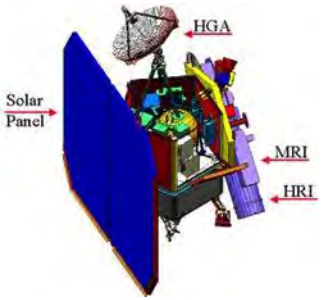
A-Team Methods

CML 1

Capturing ideas and linking associated ideas

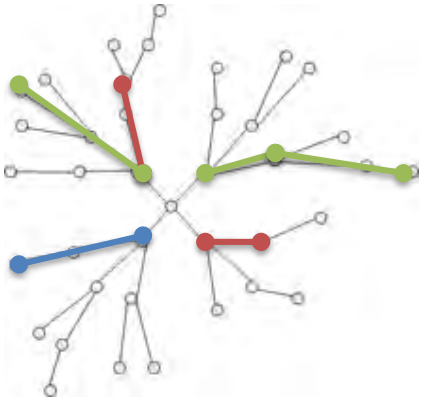




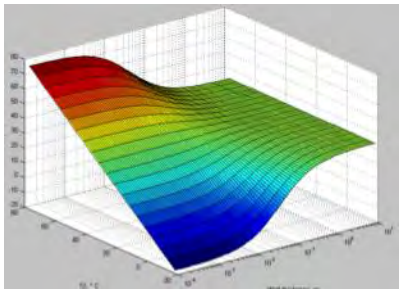
Research, bringing in previous studies

CML 2

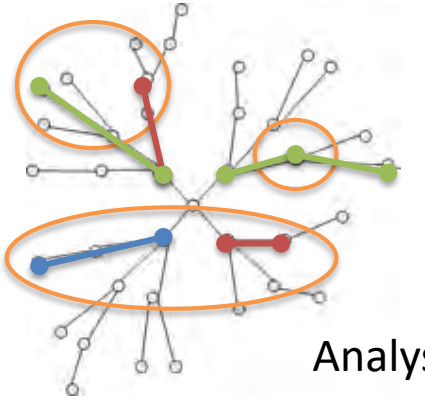
Testing assumptions, relationships, and links



Analyzing feasibility, finding FOMs and thresholds

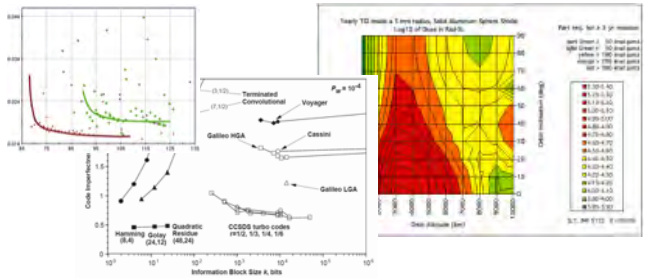


CML 3

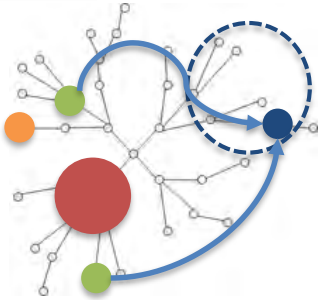


Building seed science cases and concept architectures

Analysis and trade space exploration



Rapid prototyping of concepts



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“A-Team” Mindsets

- **If you are in the room, you participate**
  - Be mindful, aware and in the moment
  - Make an effort to listen more than you speak
  - Be proactive – if you see a gap or missing role, fill it
- **We are a team of peers – that includes YOU**
  - Empathize and put yourself in different roles
  - Make your team members look good
  - Build on the ideas of others – “Yes, and…”
- **Foster trust and work at building respect**
  - Talk about crazy ideas not crazy people
  - What’s said in session stays in session
  - You have to give it to earn it
- **Encourage wild ideas and constructive play**
  - They inspire innovative, get that “last piece” concepts
  - Don’t ask for permission, plenty of forgiveness
  - Prepare yourself to be wrong (and be ok with it)
- **Prototype to create, test, learn, teach, then repeat to improve**
  - Get ideas quickly into the physical world and share
  - Discovery is key – learn something new every day
  - Celebrate failure – laugh it off!

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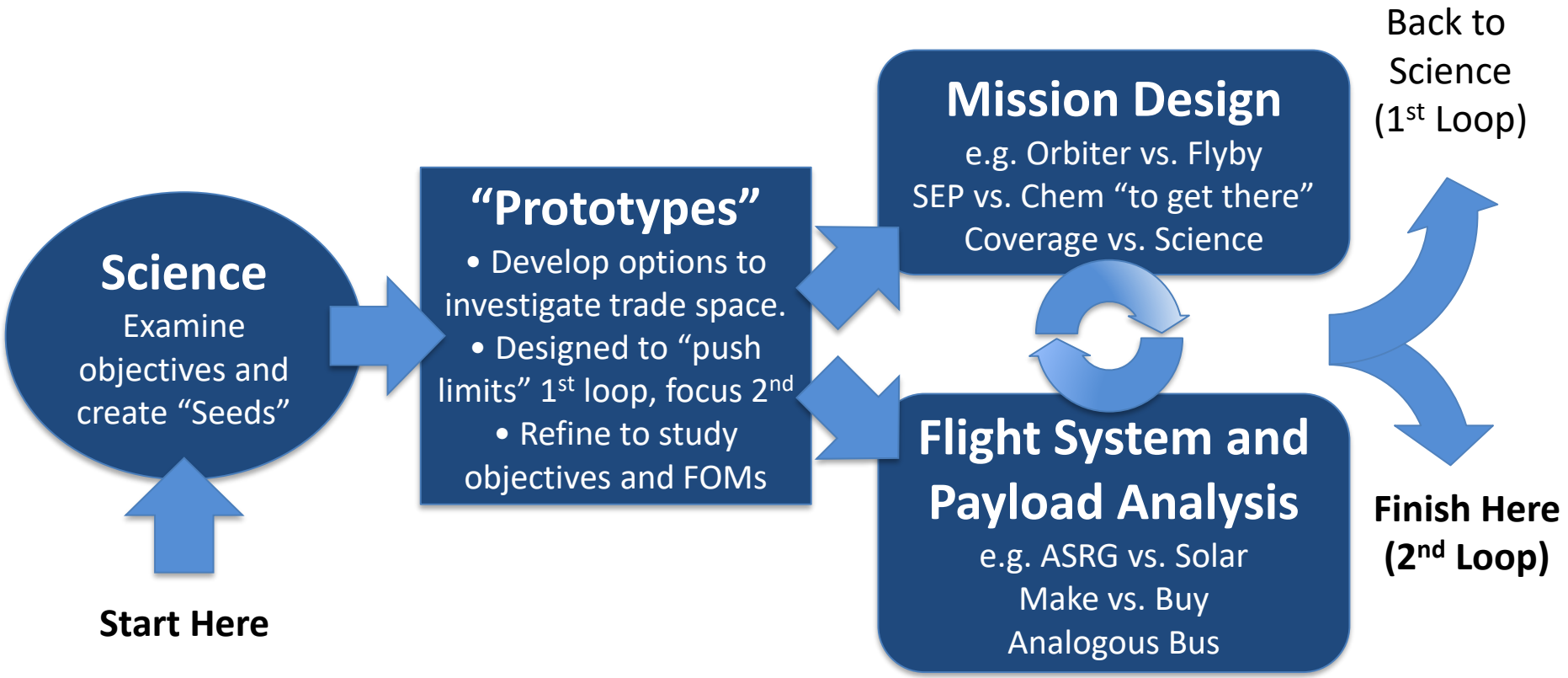
Science-driven Study Process



- Often early parts of the study include scientists and instrument specialists to help define the science "seeds"
- CML 3 study requires multiple sessions, but the people are always involved as needed – no "flies on the wall"; updates available on wiki

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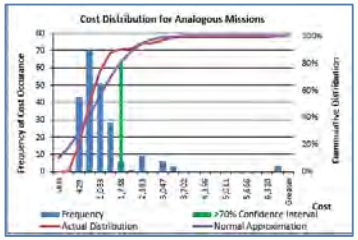
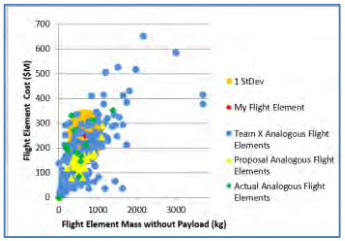
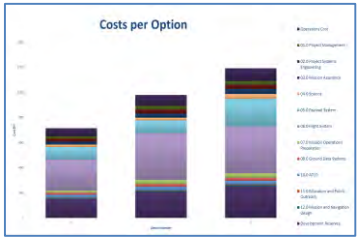
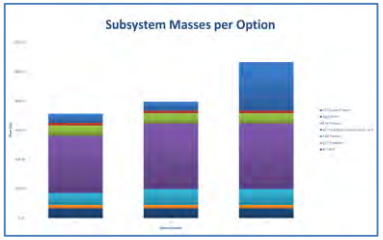
A-Team Tools









- Knowledge Capture and Management
  - Wiki-based information sharing
  - IT software and capture hardware
- Science Traceability, Thresholds, and Value
- Mission, Flight System, and Payload Design
  - 5 minute mission design
  - “Baseball Cards” for flight systems
  - Physics-based instrument sizing tools
- Cost, Complexity, and Risk
  - CML 1, 2, and multiple CML 3 cost tools
- Mission Design for Chemical and SEP
- Trade-space rapid analysis tool
- Model-based tools and databases soon to be operational

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Future Improvements

- Three new major initiatives
  - “Forging” Sessions
  - Technology Infusion
  - Trade Space Exploration
- Using our new infrastructure
- Getting out to a broader community
- Training new people and more roles
- Product development, speed, and quality
- Reviewing what we’ve done
- Tracking results post-study

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Summary

From >200 studies, The A-Team is:

- An accessible and proven way for JPL to explore trade spaces and mature ideas into concepts
- A wealth of knowledge on early concepts, science investigations, and technology needs and impacts
- A reliable and configurable process
- A collection of people, ideas, and objects that promotes new connections and innovations at JPL
- A testing ground for new processes, tools and developing best practices in early concept formulation

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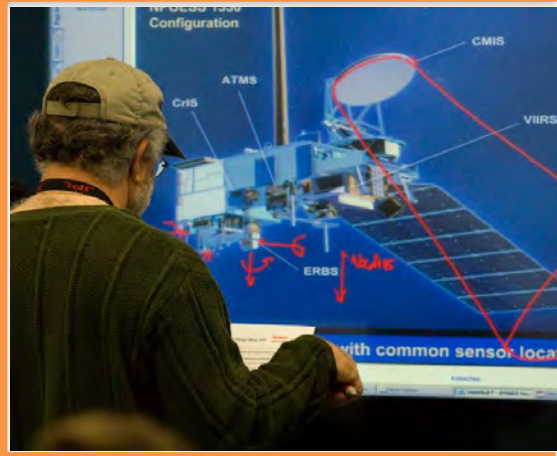
active
corpus
callosum

Concept for an outerplanet Probe
mass= 940KG
Pwr: MMRTG
EXIT

TEAM X
Jet Propulsion Laboratory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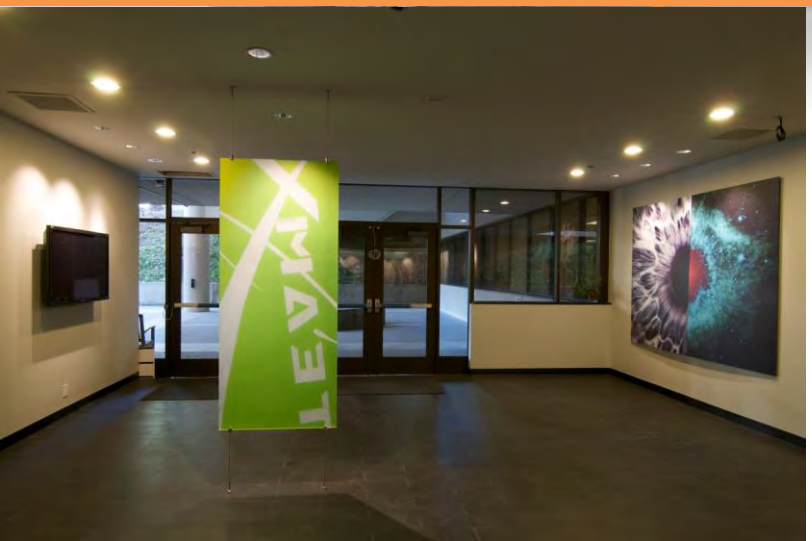
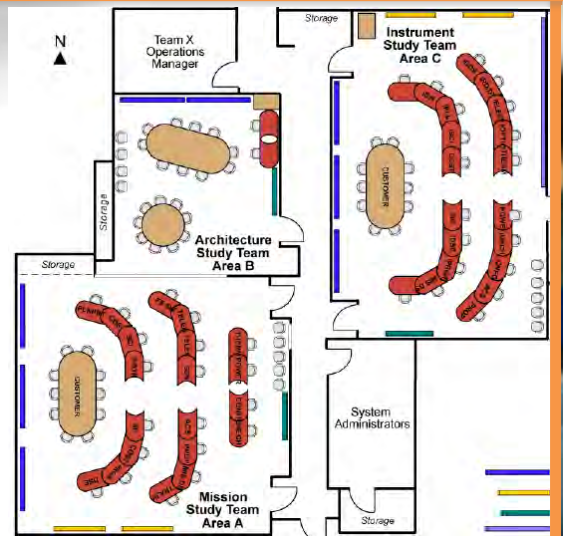
VIIRS
ERBS


TEAM X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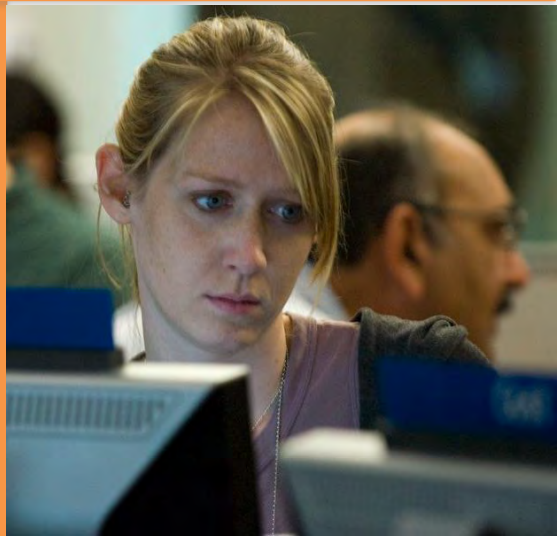
Storage
Instrument Study Team Area C
Architecture Study Team Area B
System Administrators
Mission Study Team Area A



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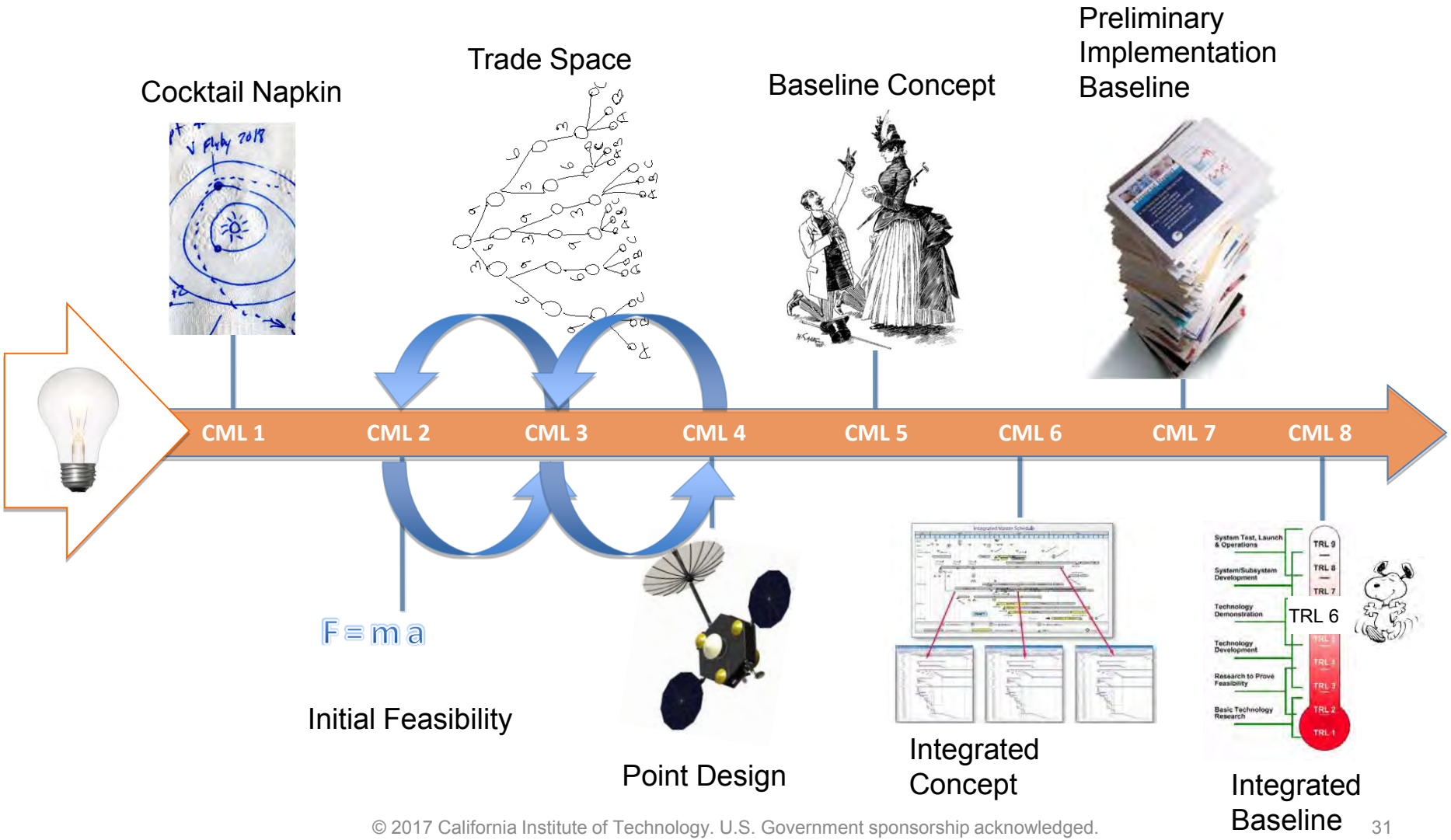
CMLs: A Powerful Communication Tool



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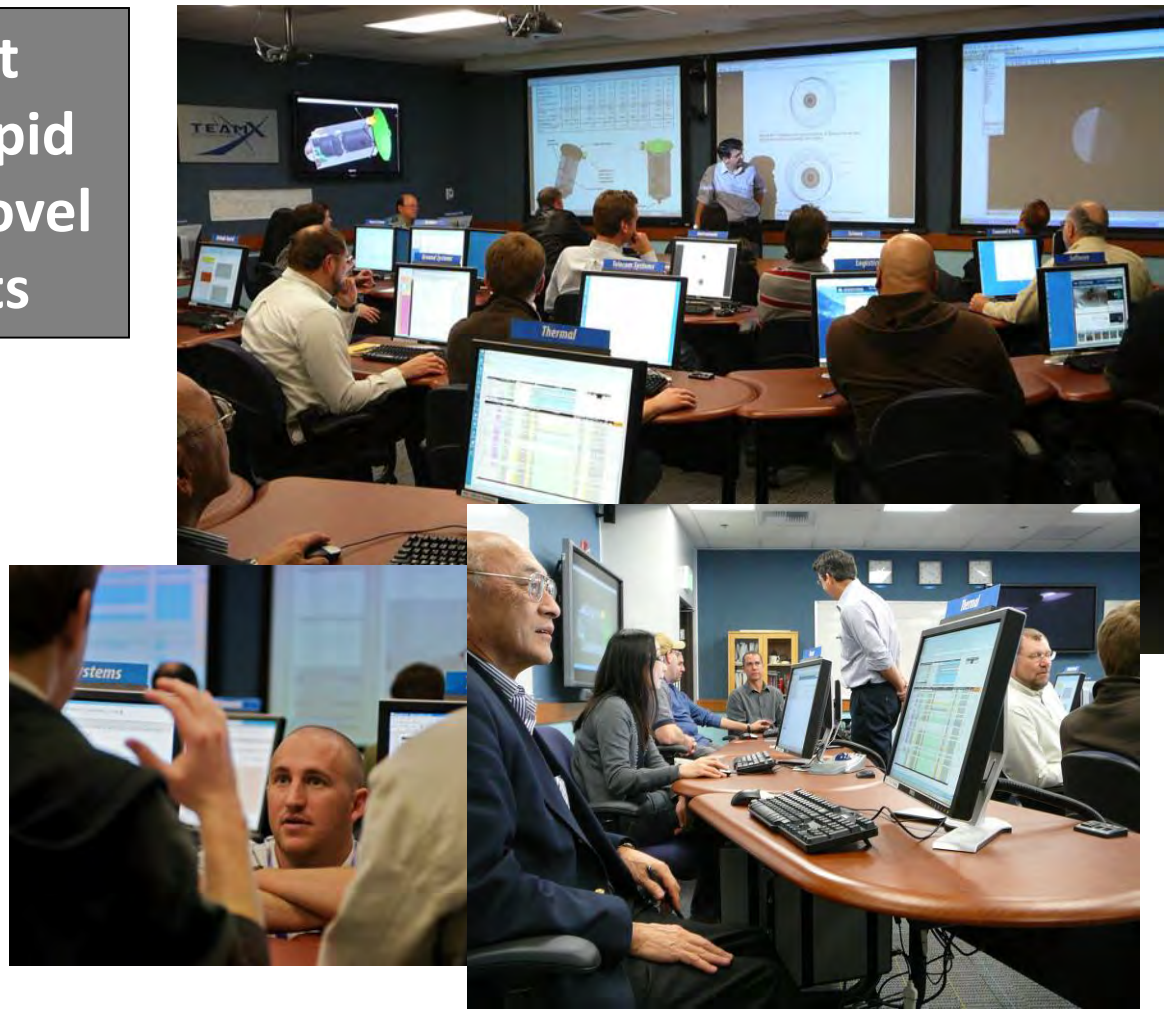
>>10^3 Team X Studies

Team X is a concurrent engineering team for rapid design and analysis of novel space mission concepts

- Backed by refined and validated, institutionally supported, integrated tools, models, and processes
- Staffed and backed by doing organizations
- Well-suited for all aspects of Pre-Phase A and Phase A design activities



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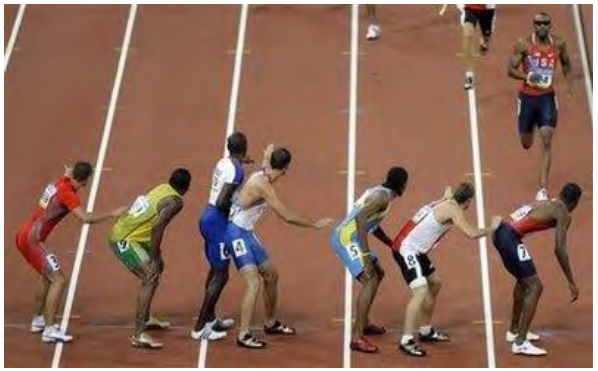
What is Concurrent Engineering?

- Traditional Mission Concept Method – Serial



- Concurrent Engineering Approach – Parallel
  - Diverse specialists working in real time, in the same place, with shared data, to yield an integrated design

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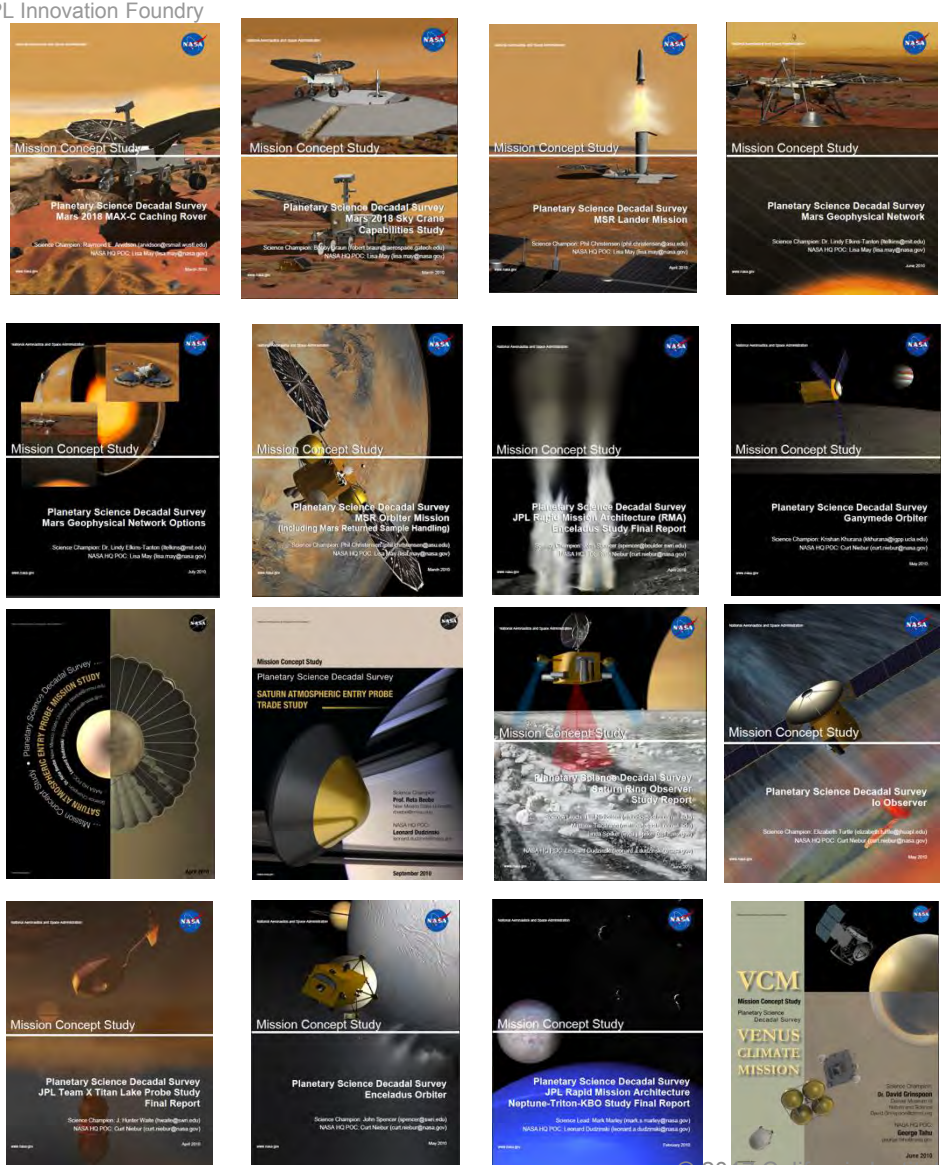
High Visibility Products for NASA



- Team X supported 16 mission concepts for Planetary Science Decadal Survey
- Team X supported 14 instrument and mission concepts for Astrophysics 2009 Decadal Survey

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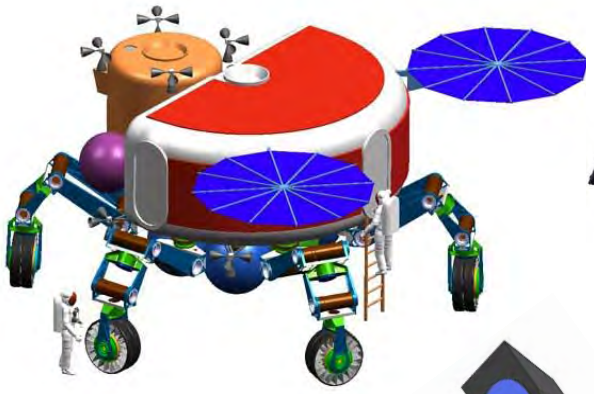
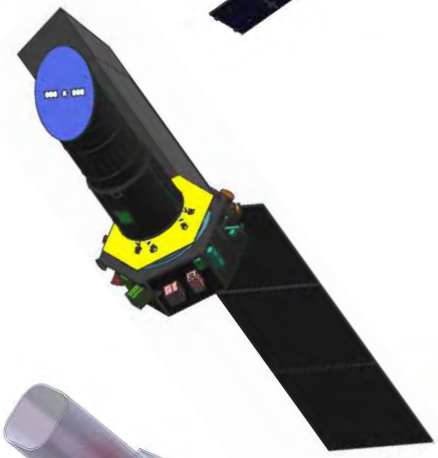
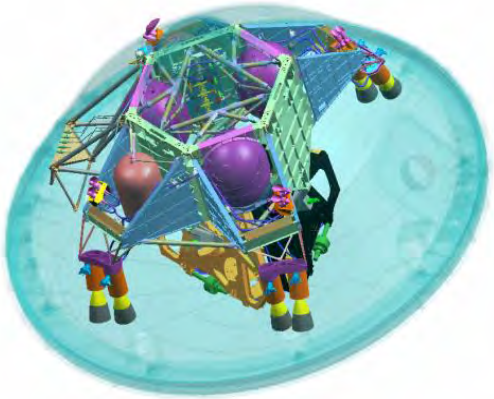
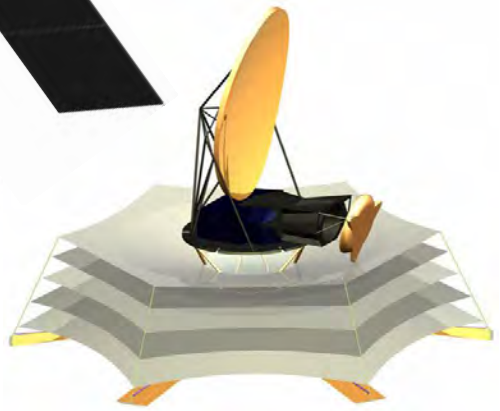
Broad Mission Concept Capabilities

- Space Missions
  - Planetary
  - Mars
  - Earth
  - Lunar
  - Astrophysics
  - Human/Robotics
  - S/C Constellations
- Flight Systems
  - Orbiters
  - Rovers
  - Landers
  - Aerobots
  - Smallsats
- Instruments
  - Remote sensing
  - *In situ*





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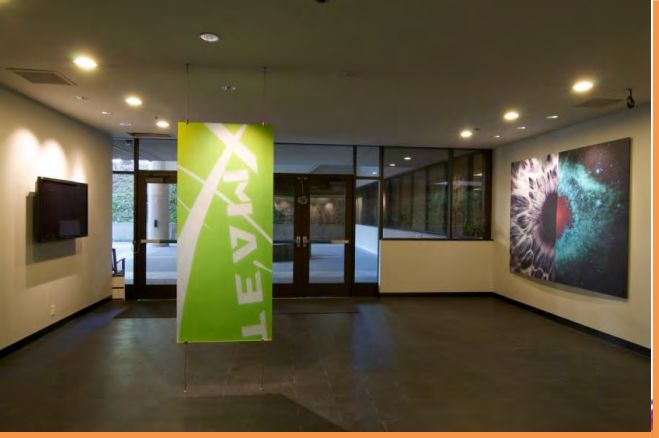

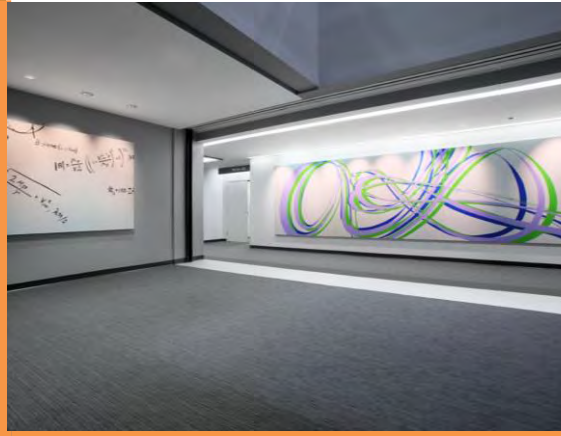
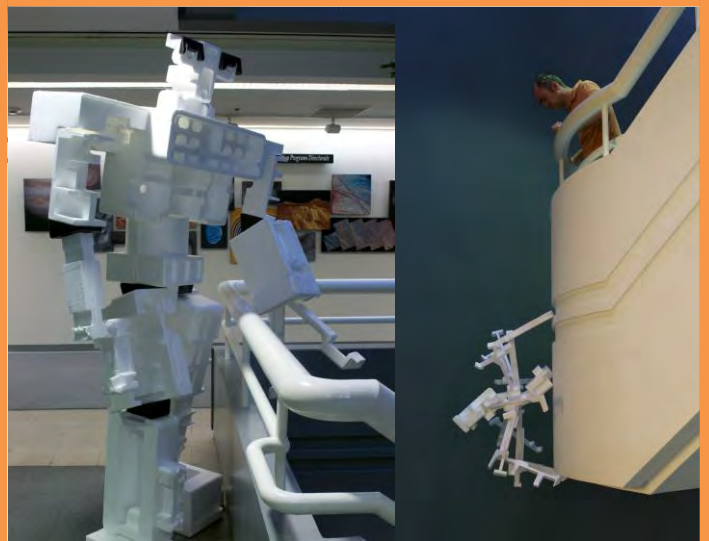
PROJECT FORMULATION