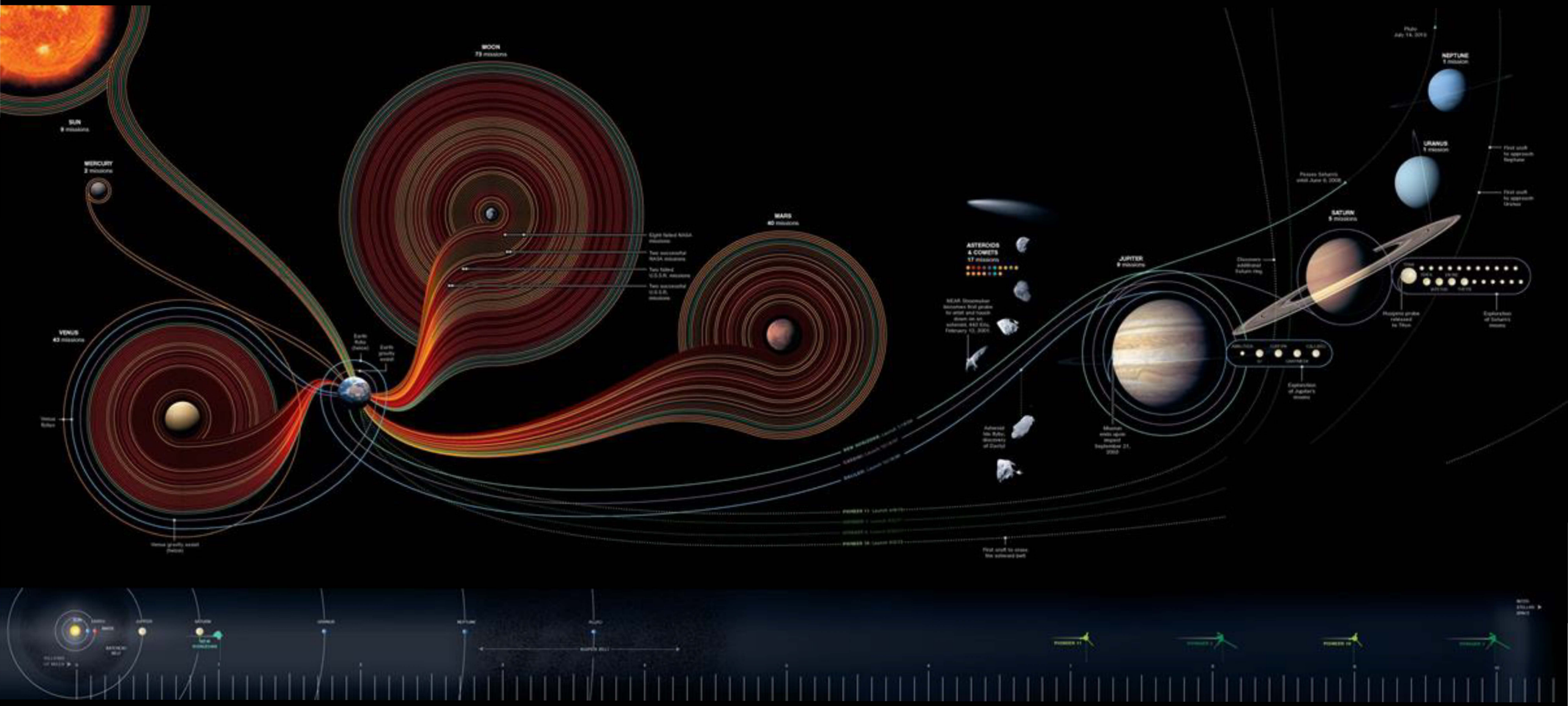
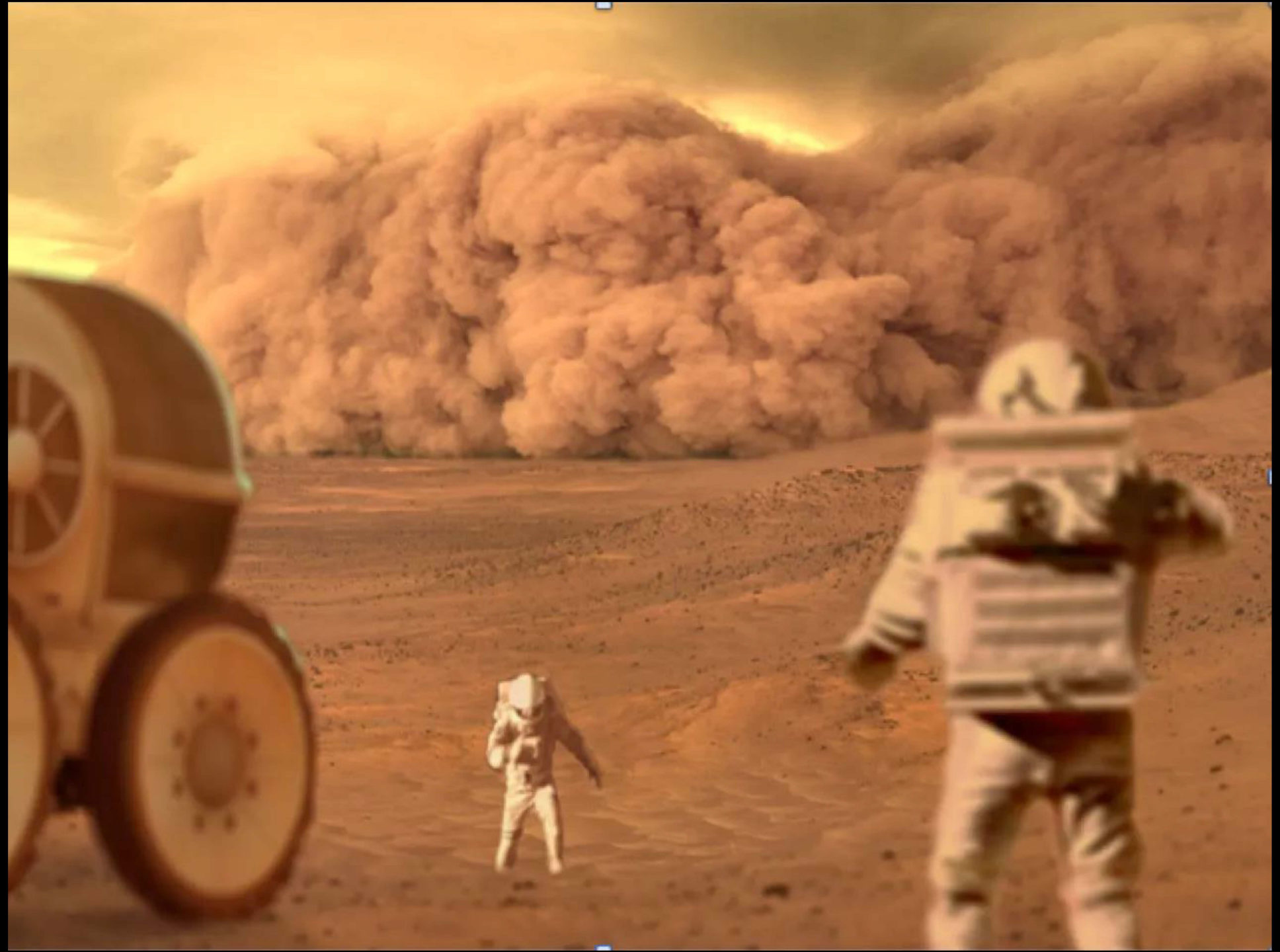
Space Mission Design at NASA Ames

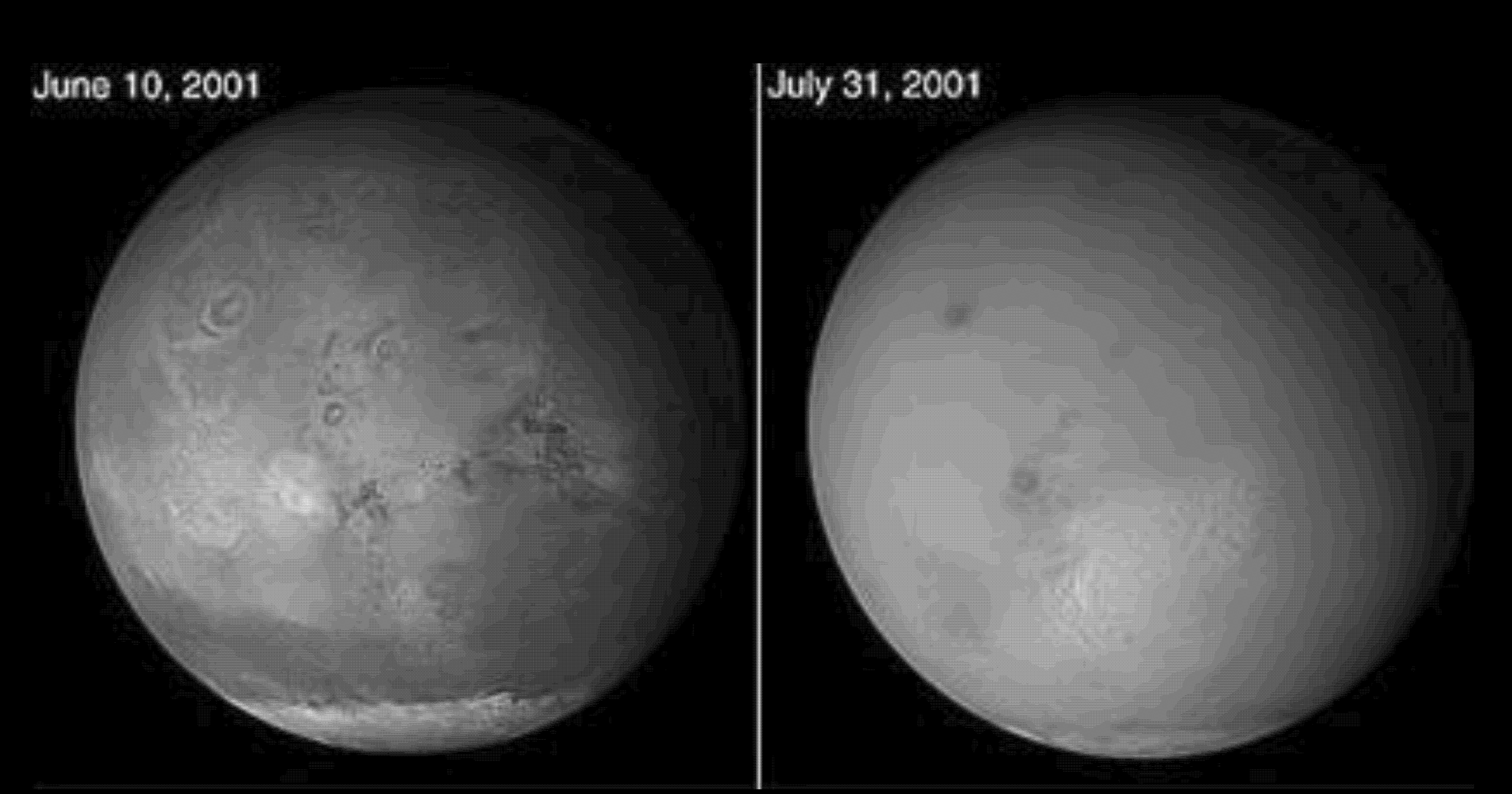
David Mauro, SGT Inc.

NASA Ames Mission Design Center

David.mauro@nasa.gov


SUN
9 missions
MERCURY
2 missions
VENUS
43 missions
MOON
73 missions
MARS
40 missions
ASTEROIDS & COMETS
17 missions
JUPITER
8 missions
SATURN
9 missions
URANUS
1 mission
NEPTUNE
1 mission
Pluto
July 14, 2015
Passes Saturn's orbit June 6, 2008
Discovers additional Saturn ring
First craft to approach Neptune
First craft to approach Uranus
Exploration of Jupiter's moons
Exploration of Saturn's moons
Huygens probe released to Titan
Asteroid Ida 243, discovery of Dactyl
Mission ends upon impact September 21, 2003
First craft to cross the asteroid belt
Venus gravity assist (twice)
Earth gravity assist
Earth flyby (twice)
Eight failed NASA missions
Two successful NASA missions
Two failed U.S.S.R. missions
Two successful U.S.S.R. missions
NEAR Shoemaker becomes first probe to orbit and touch down on an asteroid, 433 Eros, February 12, 2001
PIONEER 11 Launch 4/6/73
VOYAGER 1 Launch 9/5/77
VOYAGER 2 Launch 8/20/77
PIONEER 10 Launch 3/2/72

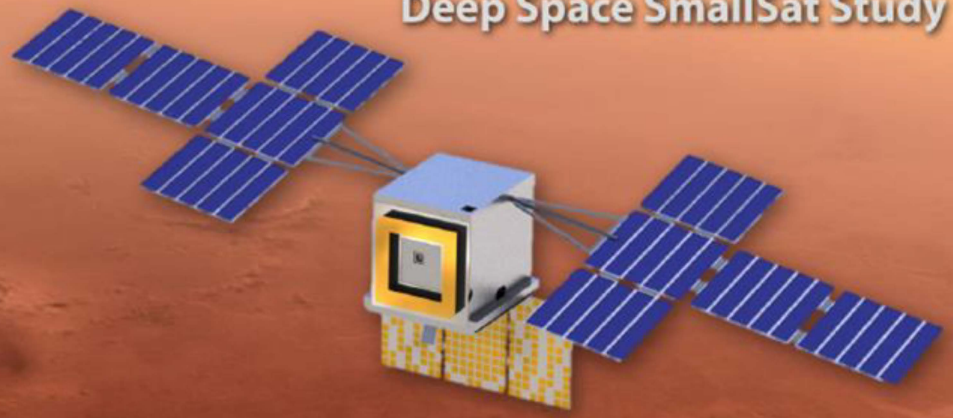



June 10, 2001
July 31, 2001

Aeolus

A mission to study the winds and climate of Mars

A 2017 Planetary Science Deep Space SmallSat Study



Submitted to:
NASA Planetary Science Division
Science Mission Directorate
Study Contract #16-PSD316-0103

Principal Investigator:
Dr. Anthony Colaprete
NASA Ames Research Center

Ames Authorizing Official:
Dr. Michael Bicay
Director, Science

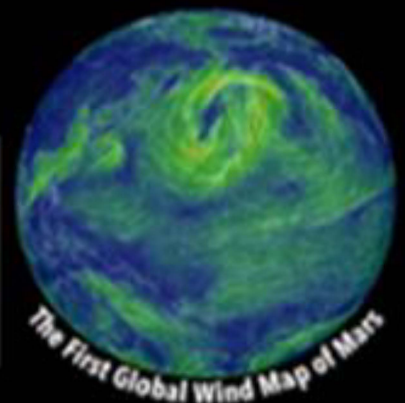
November 2017

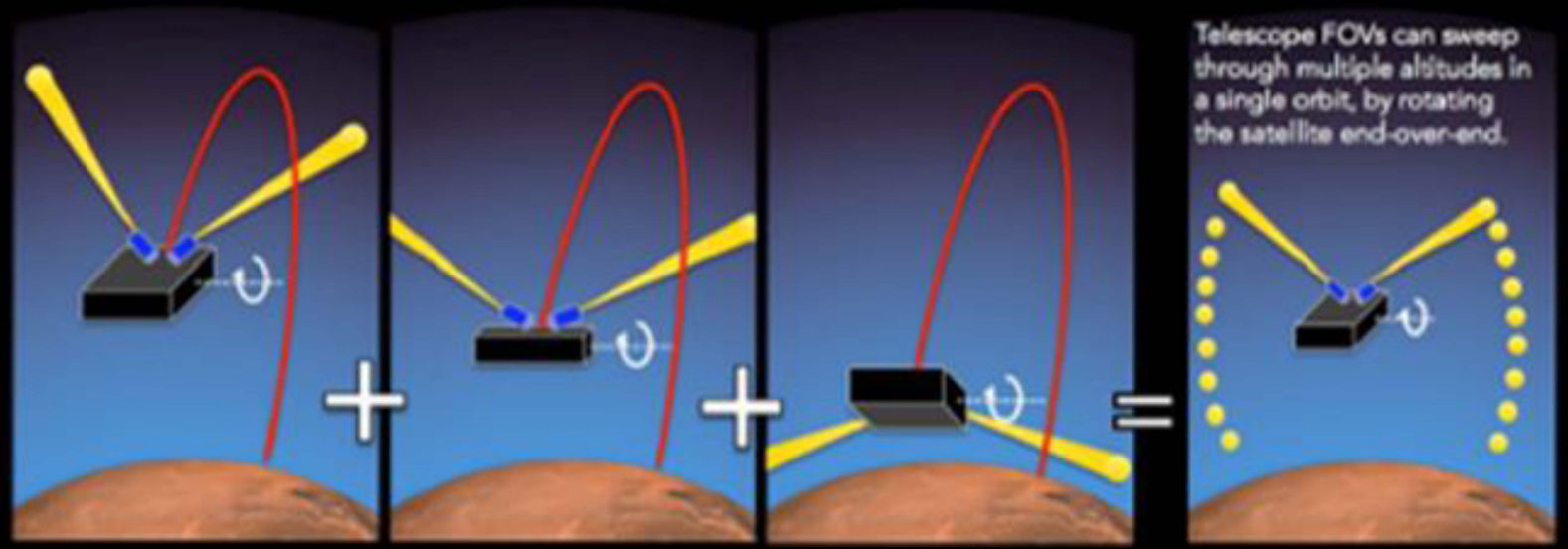

idea

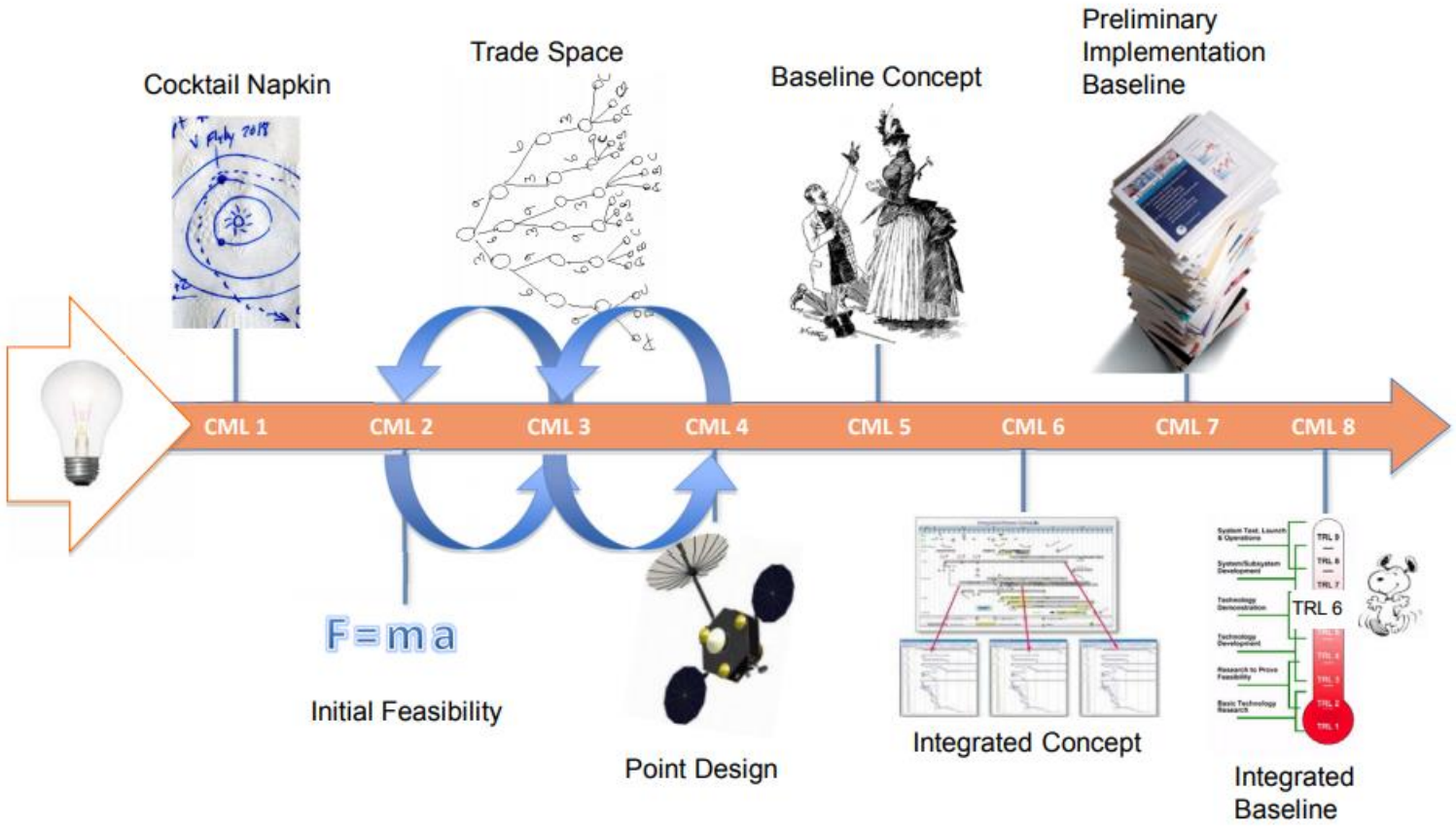


Atmospheric wind speeds have never been measured at Mars.

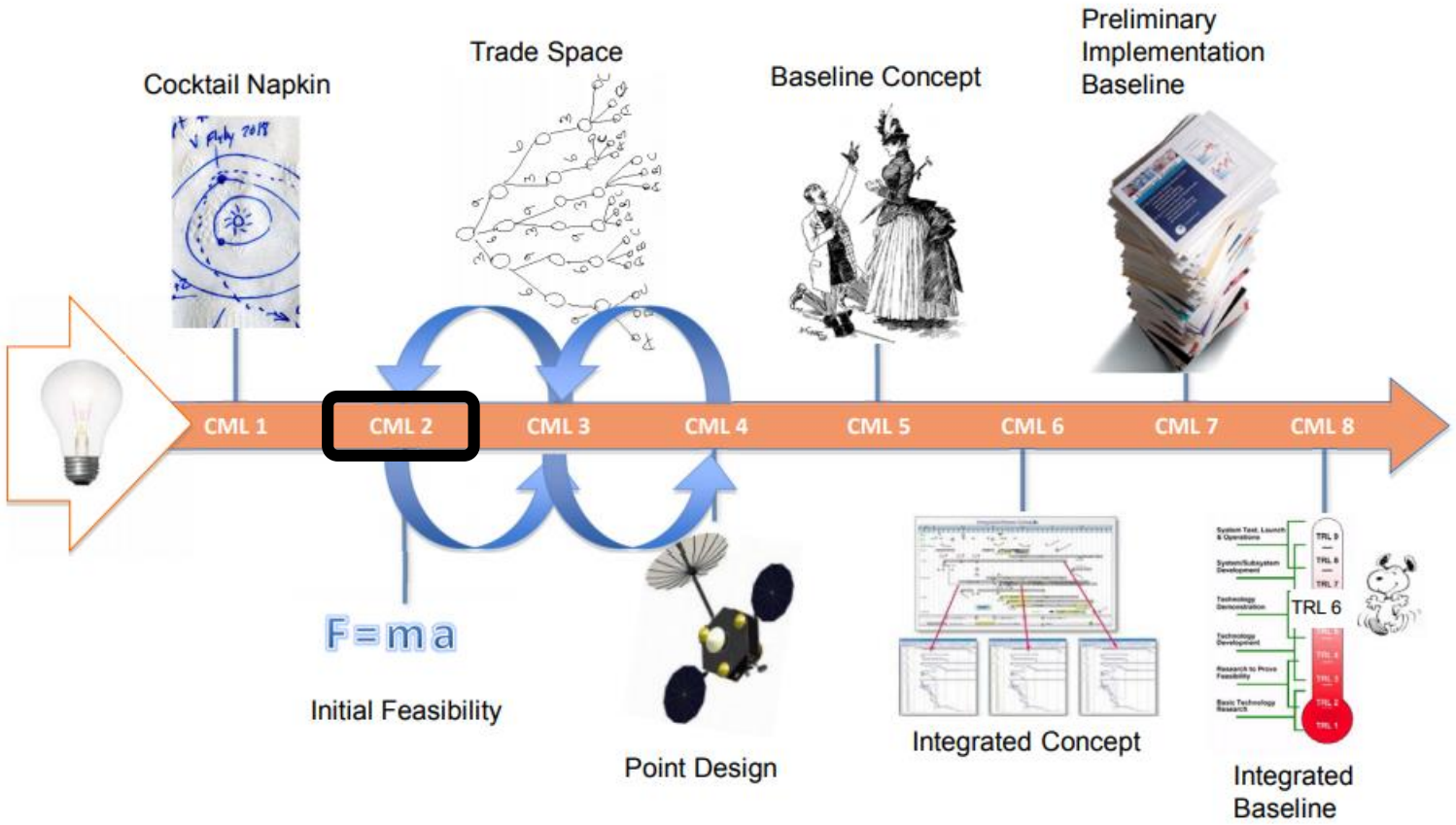
By measuring temperatures and Doppler shifts in atmospheric spectral lines, Aeolus will determine wind vectors and atmospheric temperatures at all longitudes and times of day, and multiple altitudes, creating the first global wind map of Mars.



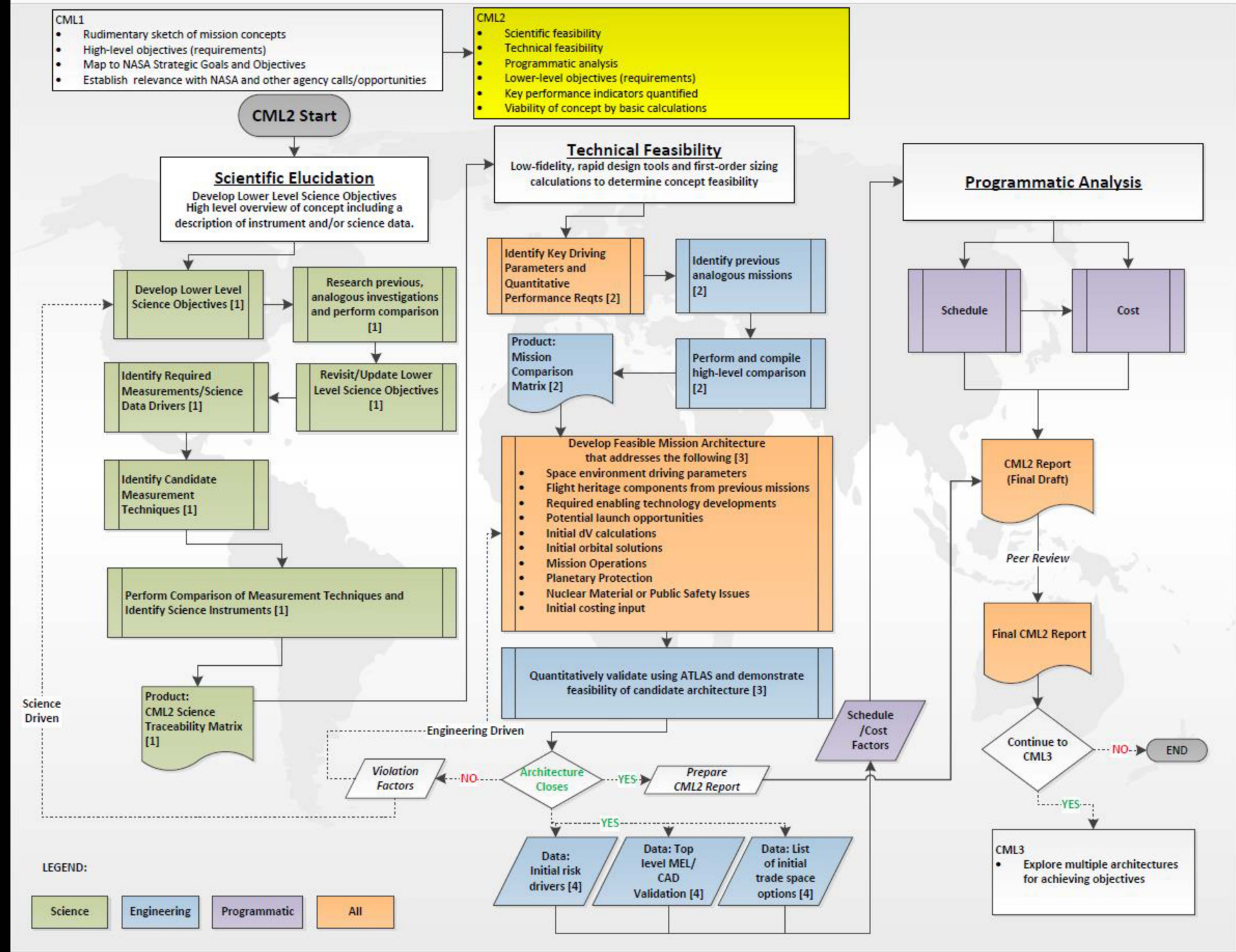


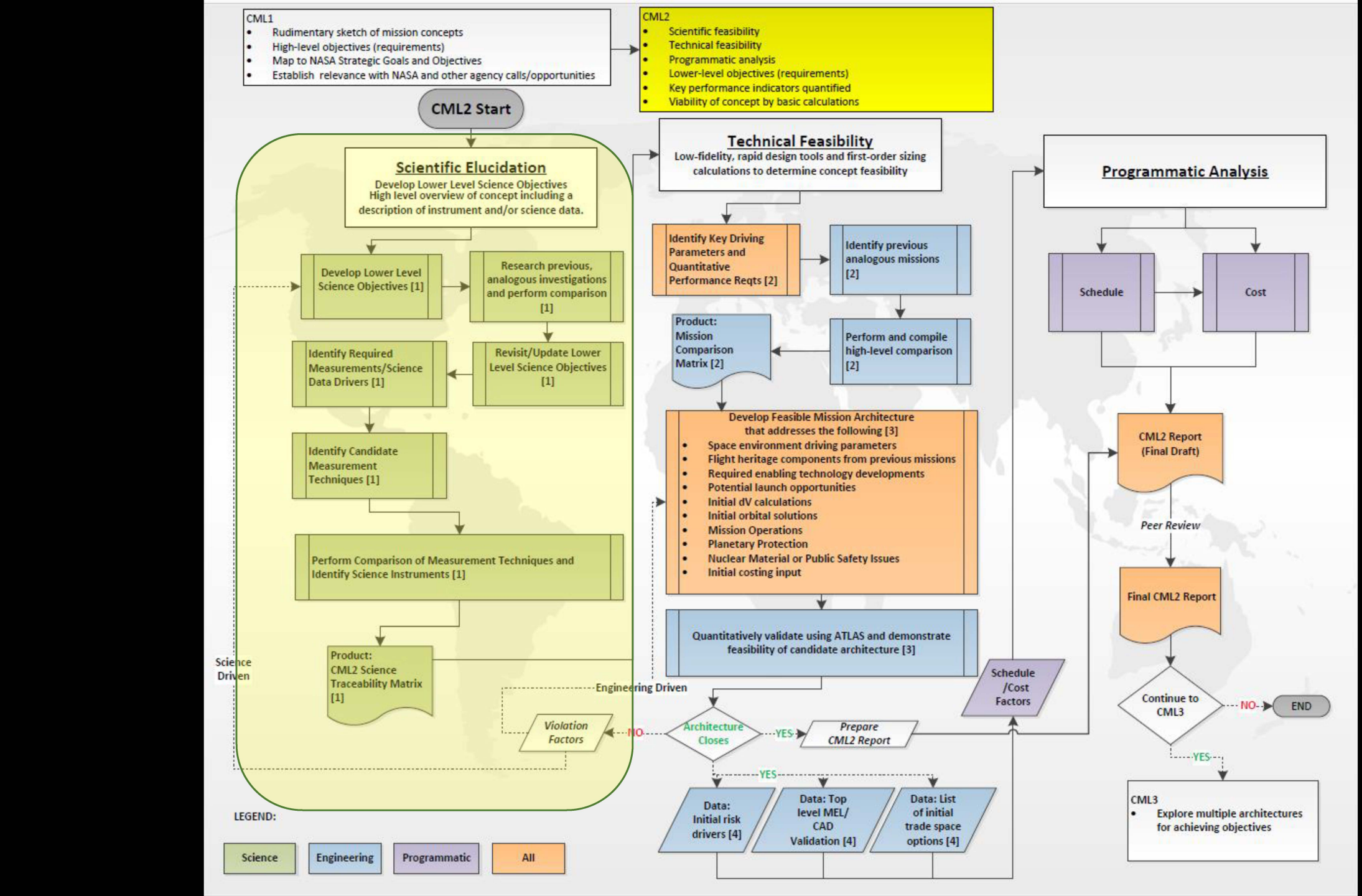

Cocktail Napkin
Trade Space
Baseline Concept
Preliminary Implementation Baseline
CML 1
CML 2
CML 3
CML 4
CML 5
CML 6
CML 7
CML 8
F=ma
Initial Feasibility
Point Design
Integrated Concept
TRL 6
Integrated Baseline

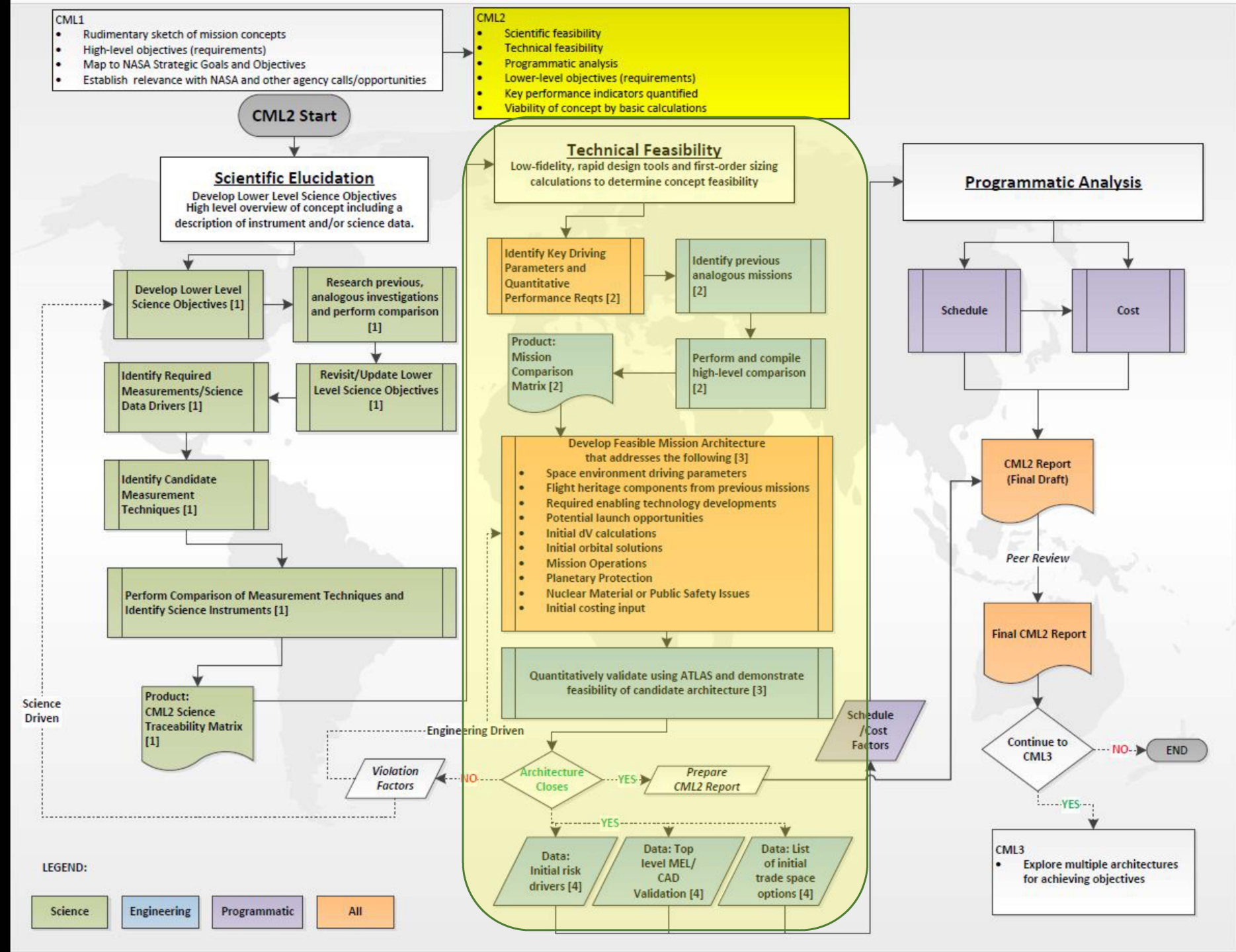
Credit: JPL

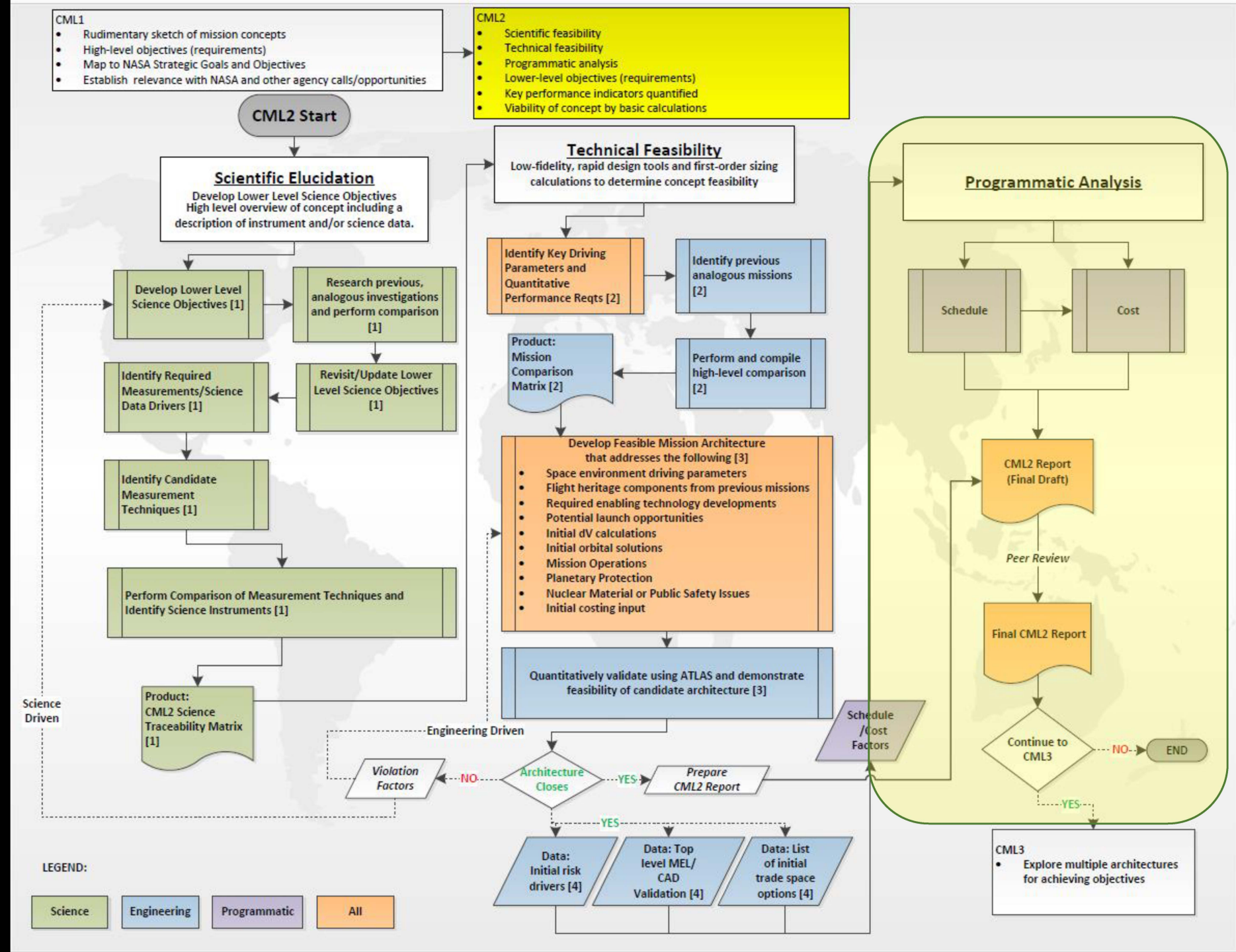

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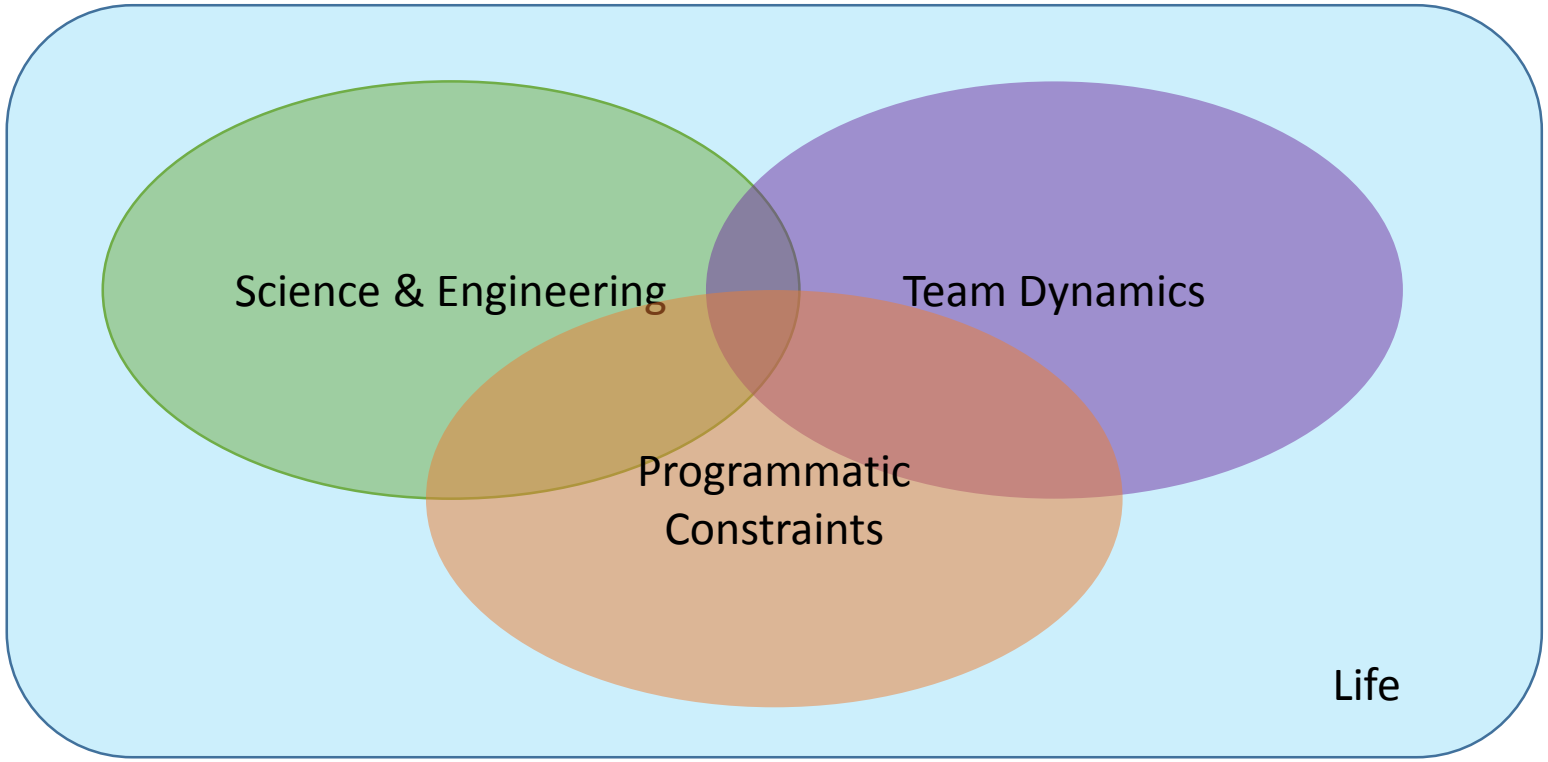

CML1
Rudimentary sketch of mission concepts
High-level objectives (requirements)
Map to NASA Strategic Goals and Objectives
Establish relevance with NASA and other agency calls/opportunities
CML2
Scientific feasibility
Technical feasibility
Programmatic analysis
Lower-level objectives (requirements)
Key performance indicators quantified
Viability of concept by basic calculations
CML2 Start
Scientific Elucidation
Develop Lower Level Science Objectives
High level overview of concept including a description of instrument and/or science data.
Develop Lower Level Science Objectives [1]
Research previous, analogous investigations and perform comparison [1]
Revisit/Update Lower Level Science Objectives [1]
Identify Required Measurements/Science Data Drivers [1]
Identify Candidate Measurement Techniques [1]
Perform Comparison of Measurement Techniques and Identify Science Instruments [1]
Product: CML2 Science Traceability Matrix [1]
Science Driven
Technical Feasibility
Low-fidelity, rapid design tools and first-order sizing calculations to determine concept feasibility
Identify Key Driving Parameters and Quantitative Performance Reqts [2]
Identify previous analogous missions [2]
Perform and compile high-level comparison [2]
Product: Mission Comparison Matrix [2]
Develop Feasible Mission Architecture that addresses the following [3]
Space environment driving parameters
Flight heritage components from previous missions
Required enabling technology developments
Potential launch opportunities
Initial dV calculations
Initial orbital solutions
Mission Operations
Planetary Protection
Nuclear Material or Public Safety Issues
Initial costing input
Quantitatively validate using ATLAS and demonstrate feasibility of candidate architecture [3]
Engineering Driven
Violation Factors
NO
Architecture Closes
YES
Prepare CML2 Report
YES
Data: Initial risk drivers [4]
Data: Top level MEL/ CAD Validation [4]
Data: List of initial trade space options [4]
Schedule /Cost Factors
Programmatic Analysis
Schedule
Cost
CML2 Report (Final Draft)
Peer Review
Final CML2 Report
Continue to CML3
NO
END
YES
CML3
Explore multiple architectures for achieving objectives
LEGEND:
Science
Engineering
Programmatic
All

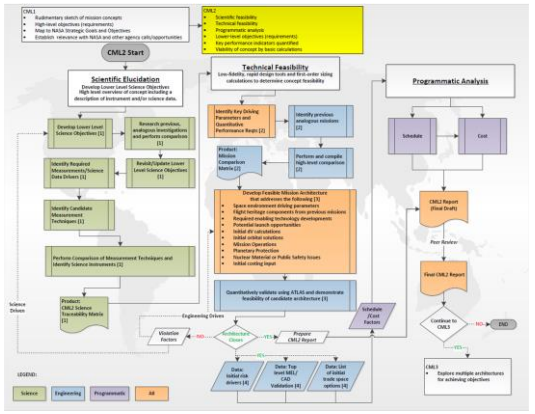

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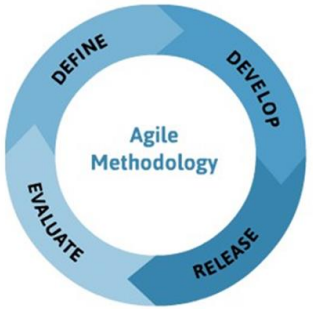
Key Tools & Best Practices

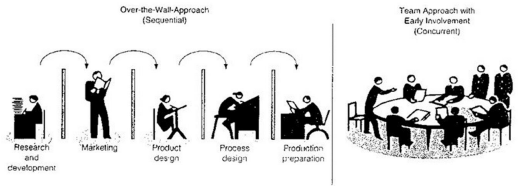




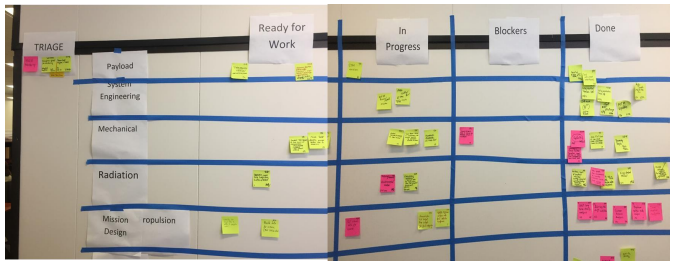












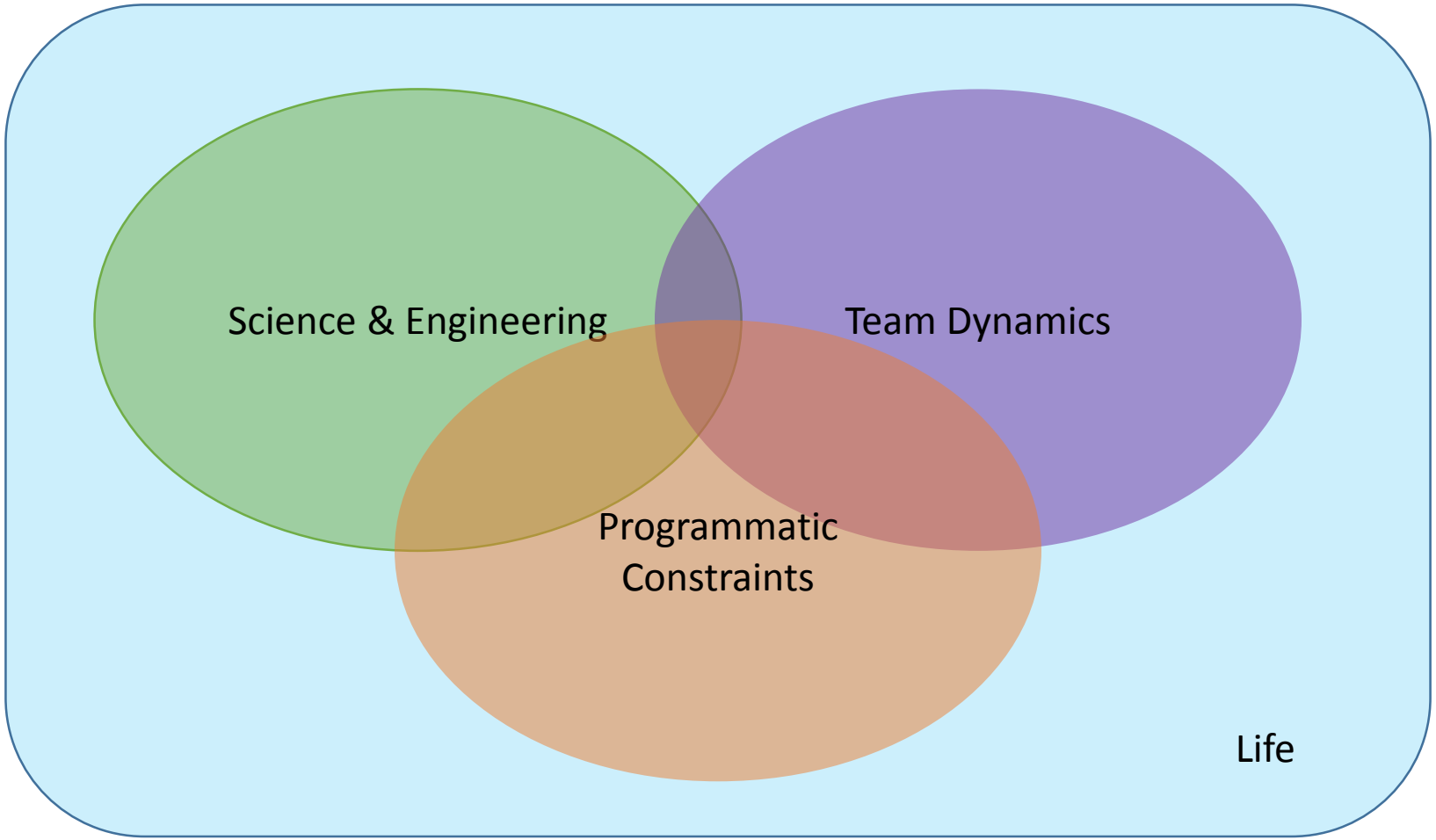






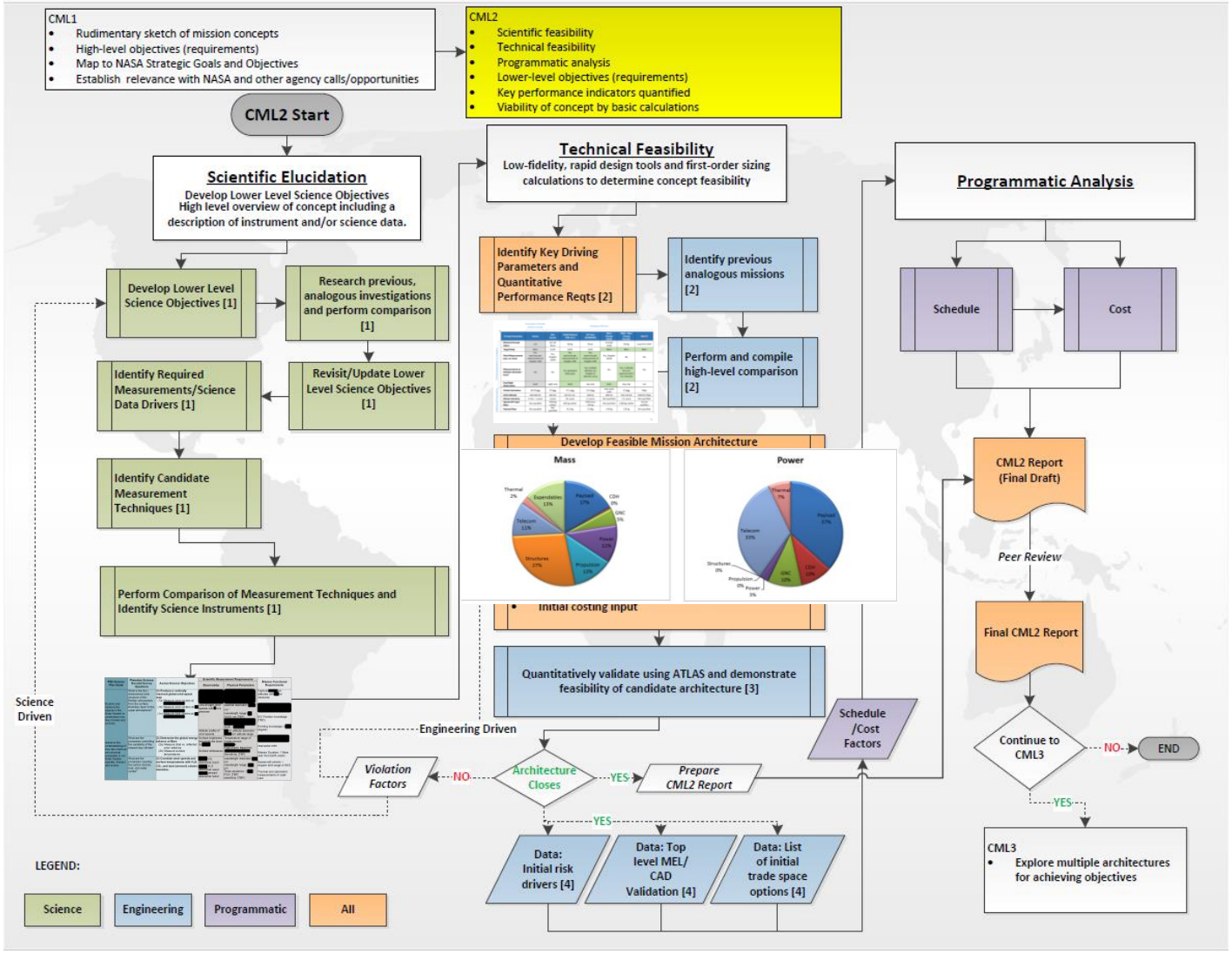


Understanding the Big Picture
Awareness of Team Dynamics & Life



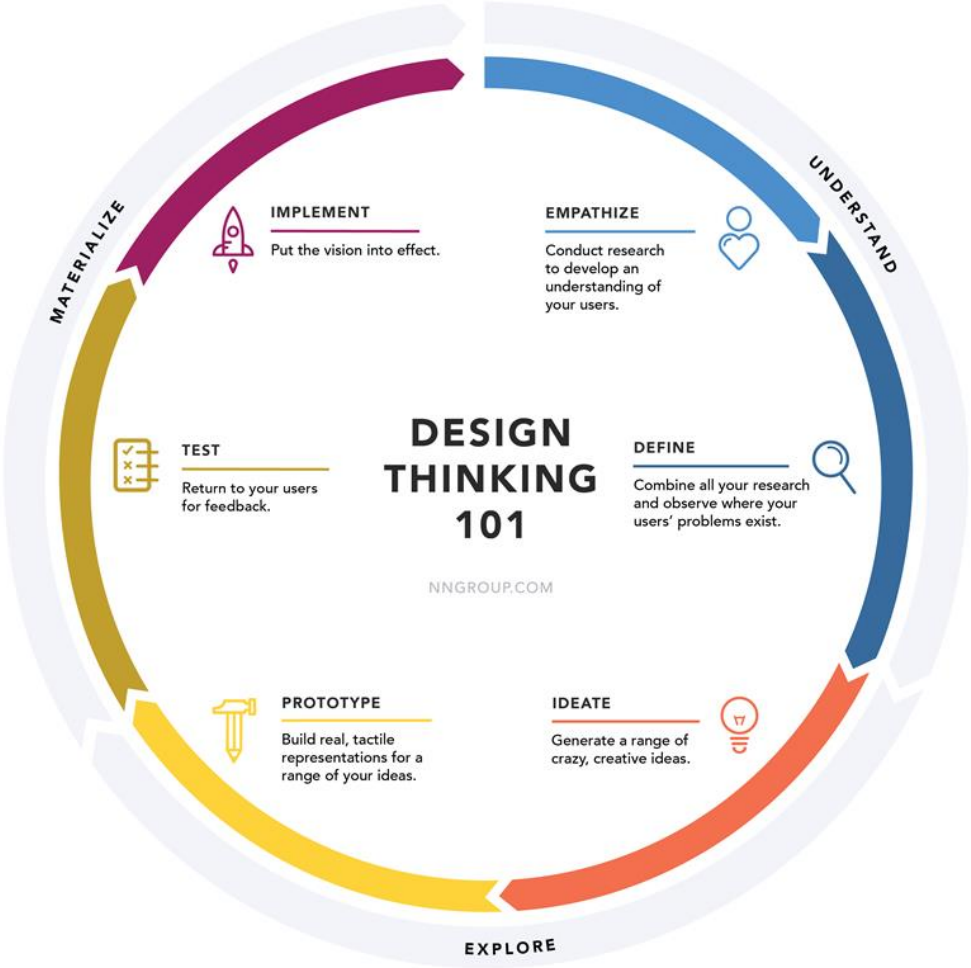
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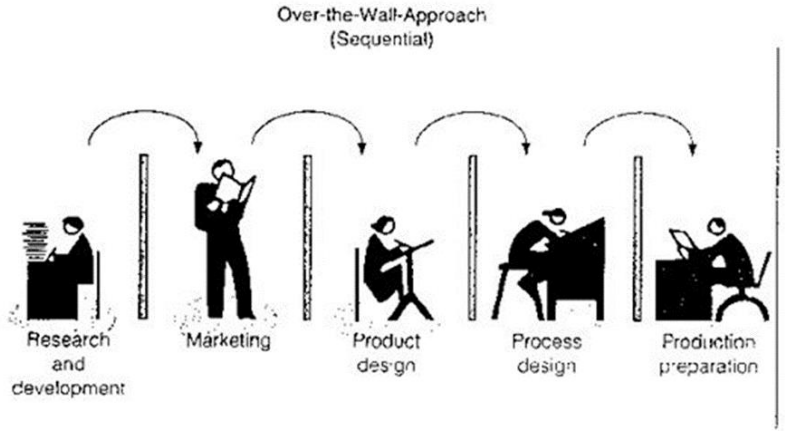
Follow a Process (or create one to follow)



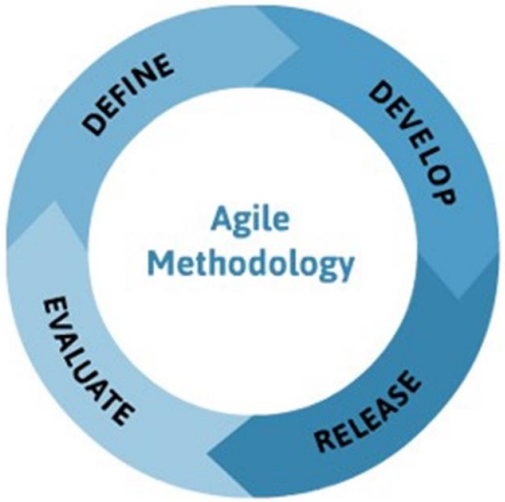
Key Tools & Best Practices

Melting Pot: Agile Principles & Concurrent Engineering & Design Thinking



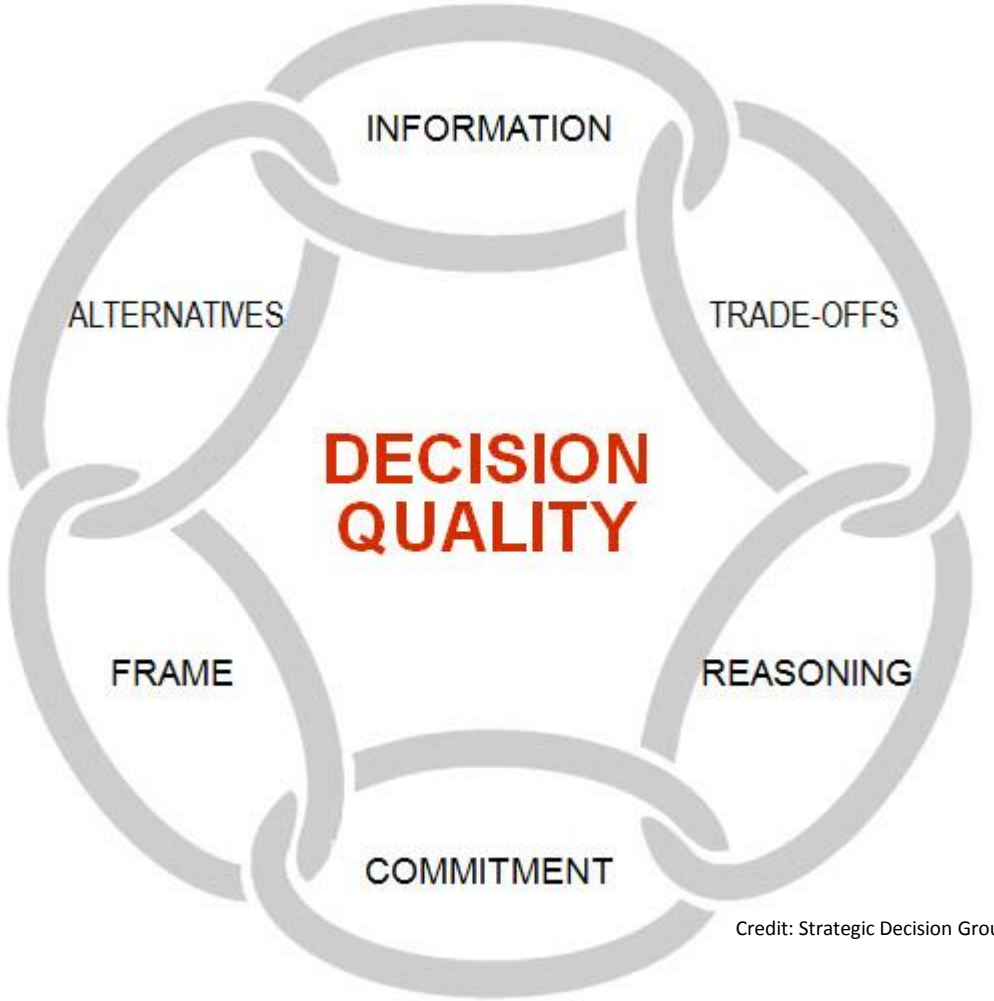






Key Tools & Best Practices

Decision Quality Chain



Credit: Strategic Decision Group

Key Tools &
Best Practices

Idea Generation









Key Tools &
Best Practices
idea generation

Brainstorming: loud voice



Key Tools &
Best Practices
idea generation

Brainstorming: silent



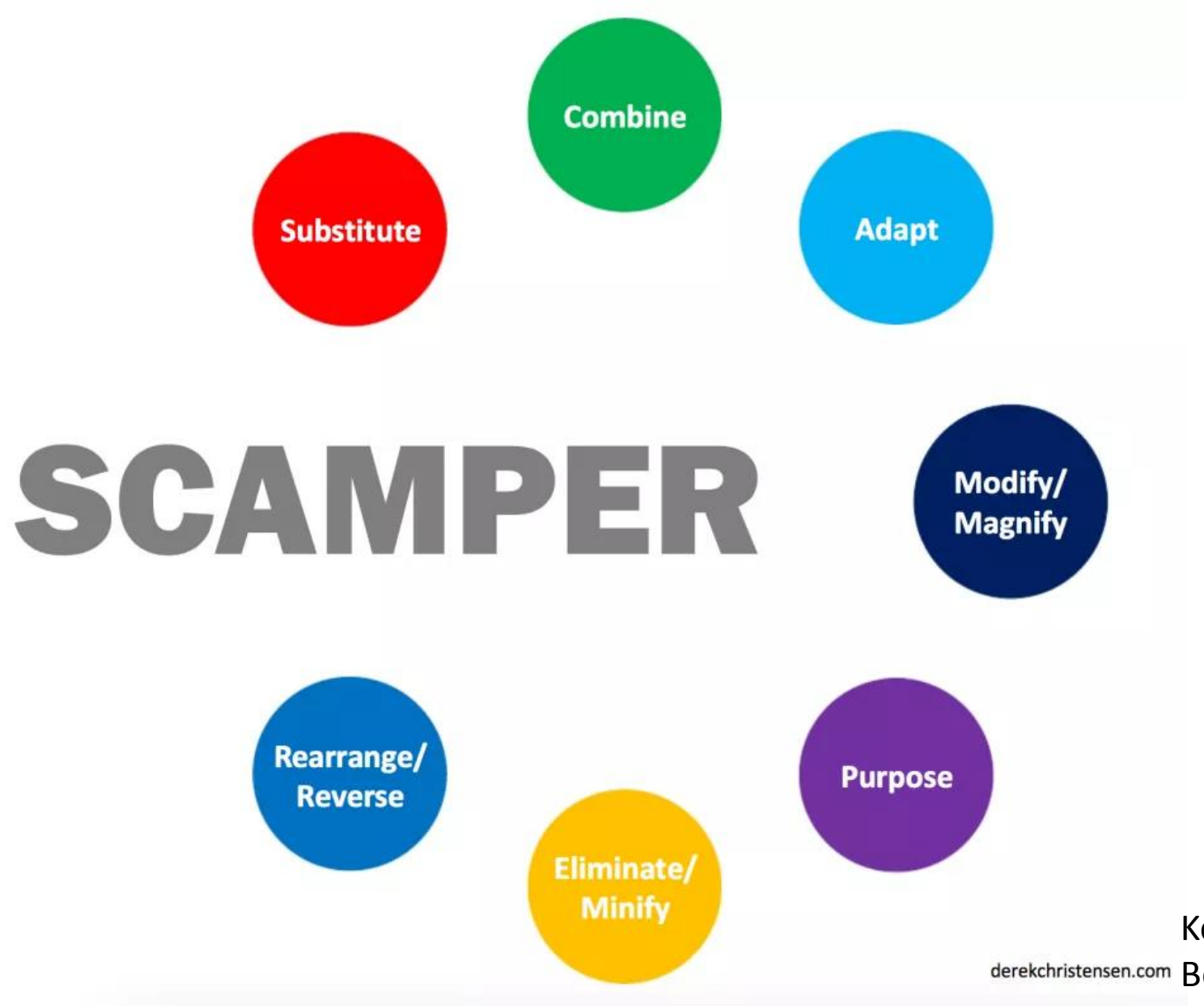
Key Tools &
Best Practices
idea generation

Forced Connection



Key Tools &
Best Practices
idea generation

SCAMPER



Key Tools &
Best Practices
idea generation

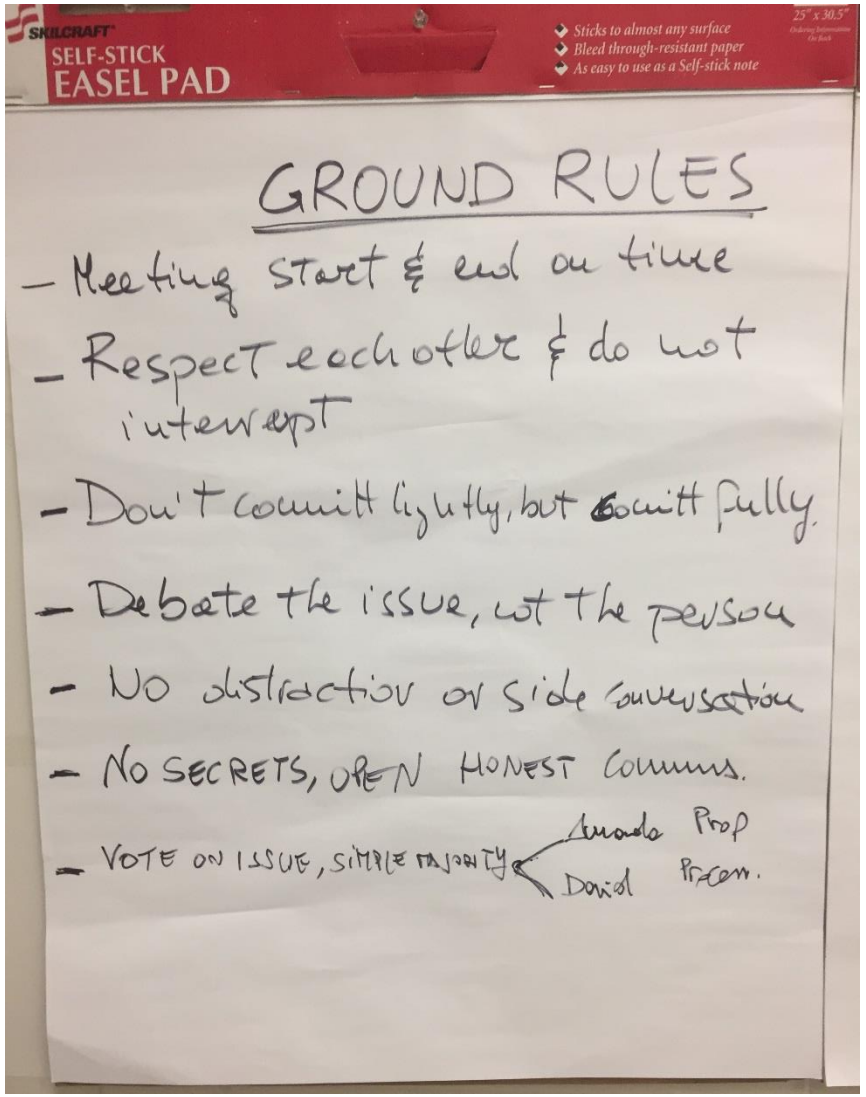
Hold a meeting only when really needed



Key Tools & Best Practices

Effective meetings

Meeting Ground Rules



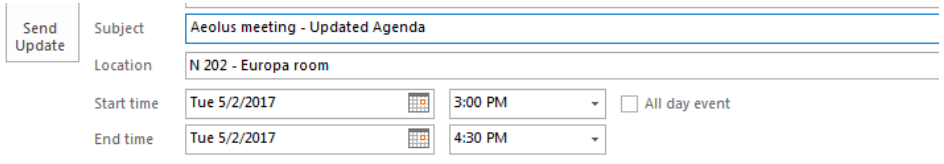
Key Tools & Best Practices

Effective meetings

Check out smartphone/tablet/pc at the door



Prepare meeting in advance



Aeolus Meeting May 2nd 0300 pm- 0430 pm – Agenda - **FINAL**

Pre-meeting activities:

- Review of MCR TEMPLATE
- Review of NASA HQ review for Aeolus
- Update R&R Matrix
- All of the above documents are here:
  M:\Projects\ROSES 2016 PSD3S\02 AEOLUS - Cook?Colaprete\Reference Material
- Review meeting minutes, here:
  M:\Projects\ROSES 2016 PSD3S\02 AEOLUS - Cook?Colaprete\PSDS3_AEOLUS\Meeting Minutes
- Review of task items, here:
  M:\Projects\ROSES 2016 PSD3S\02 AEOLUS - Cook?Colaprete\PSDS3_AEOLUS\CML 5

AGENDA

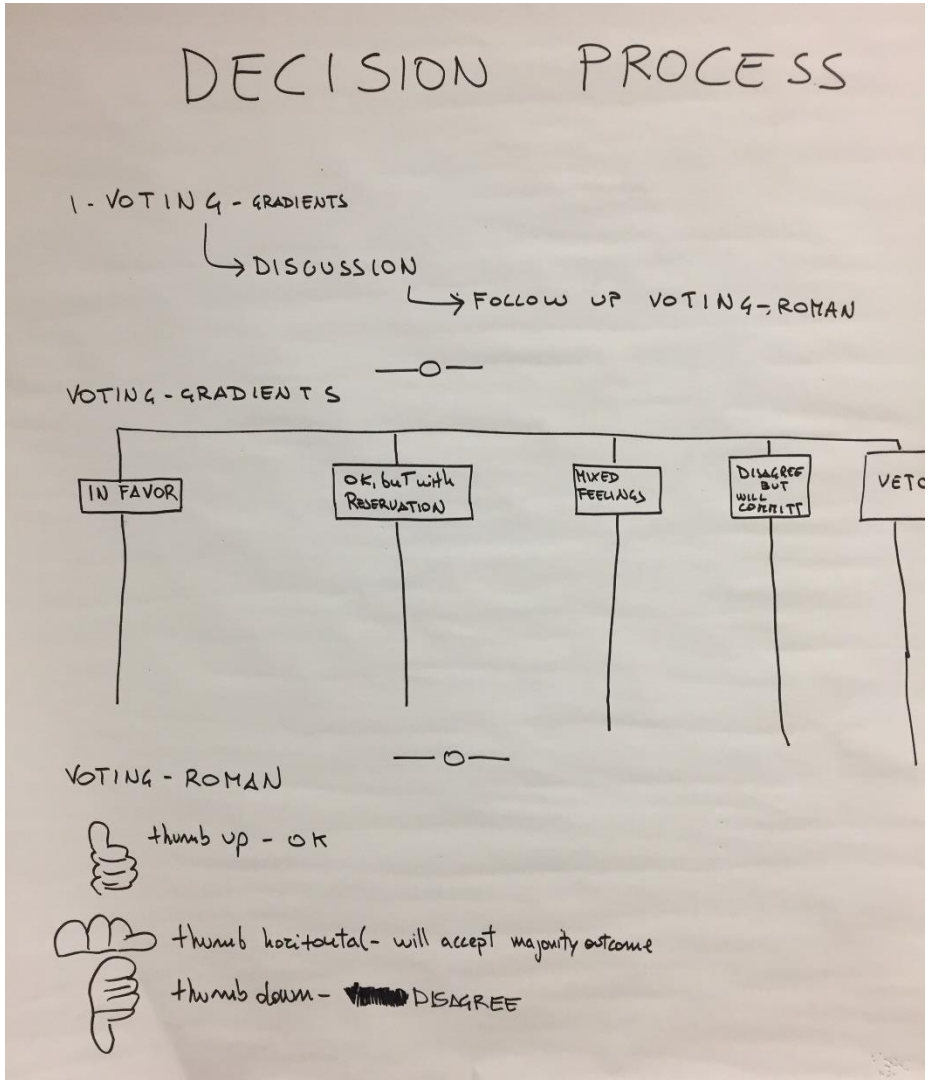
Goal of this meeting:

- **Understand how much of an issue Thermal, Radiation and Power are**
- **Review/Agree initial task assignments for CML 5 and MCR**

- Review:
  - Ground Rules
  - Goals and Success Criteria
  - Action items
  - Pre-meeting activities
- Design Status:
  - Design Board
  - Payload updates

Key Tools & Best Practices
Effective meetings

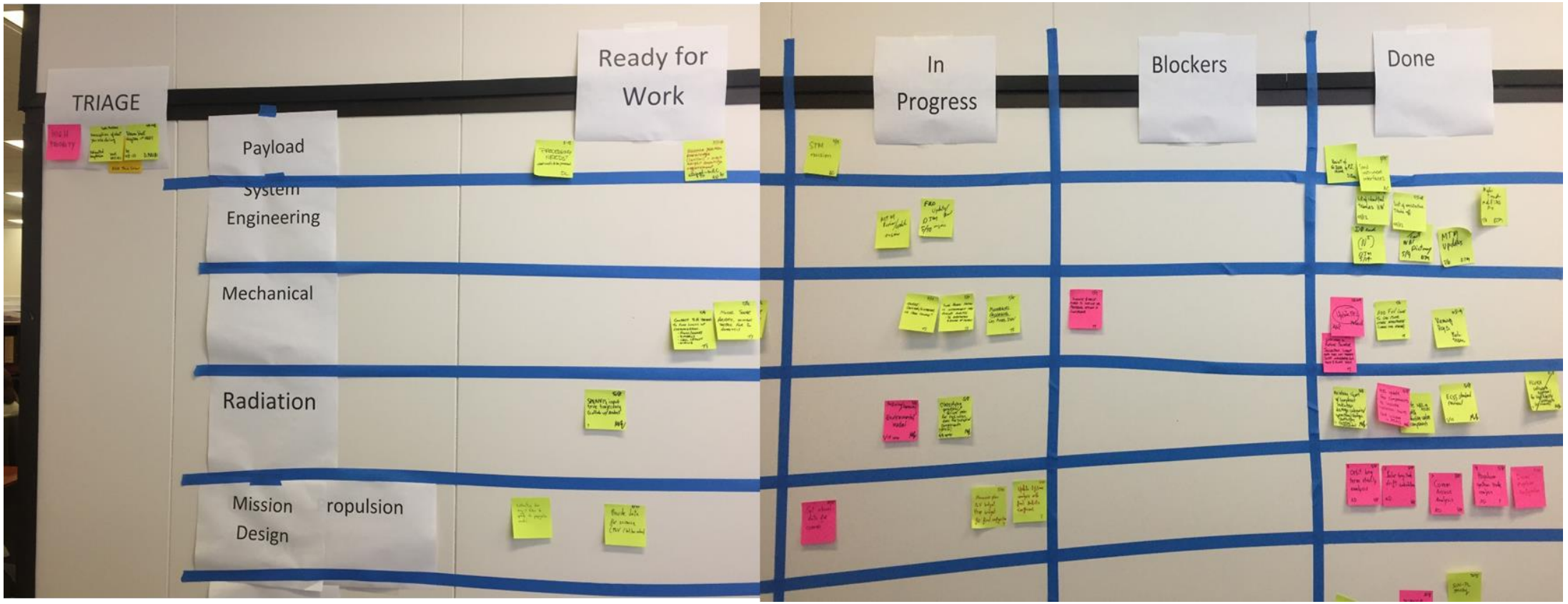
Team Voting technique



Key Tools & Best Practices

Effective meetings

Status Wall



Key Tools & Best Practices

Effective meetings

Power of positive language



Summary

- You saw the processes, principles and best practices we use at the Mission Design Center at NASA Ames to further advance ideas

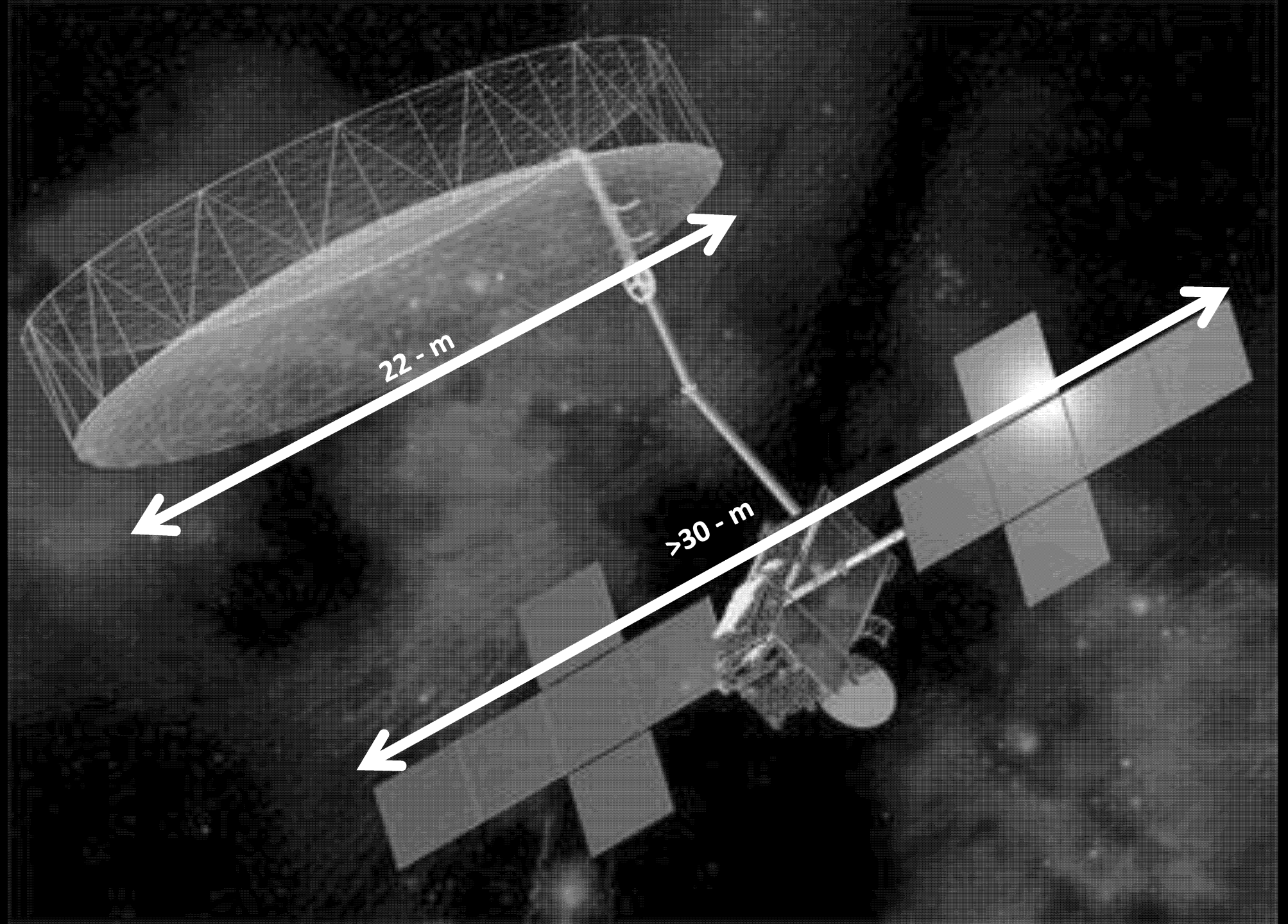
- These principles and best practices we use for designing space mission may be of use in your industry as well: give it a try!

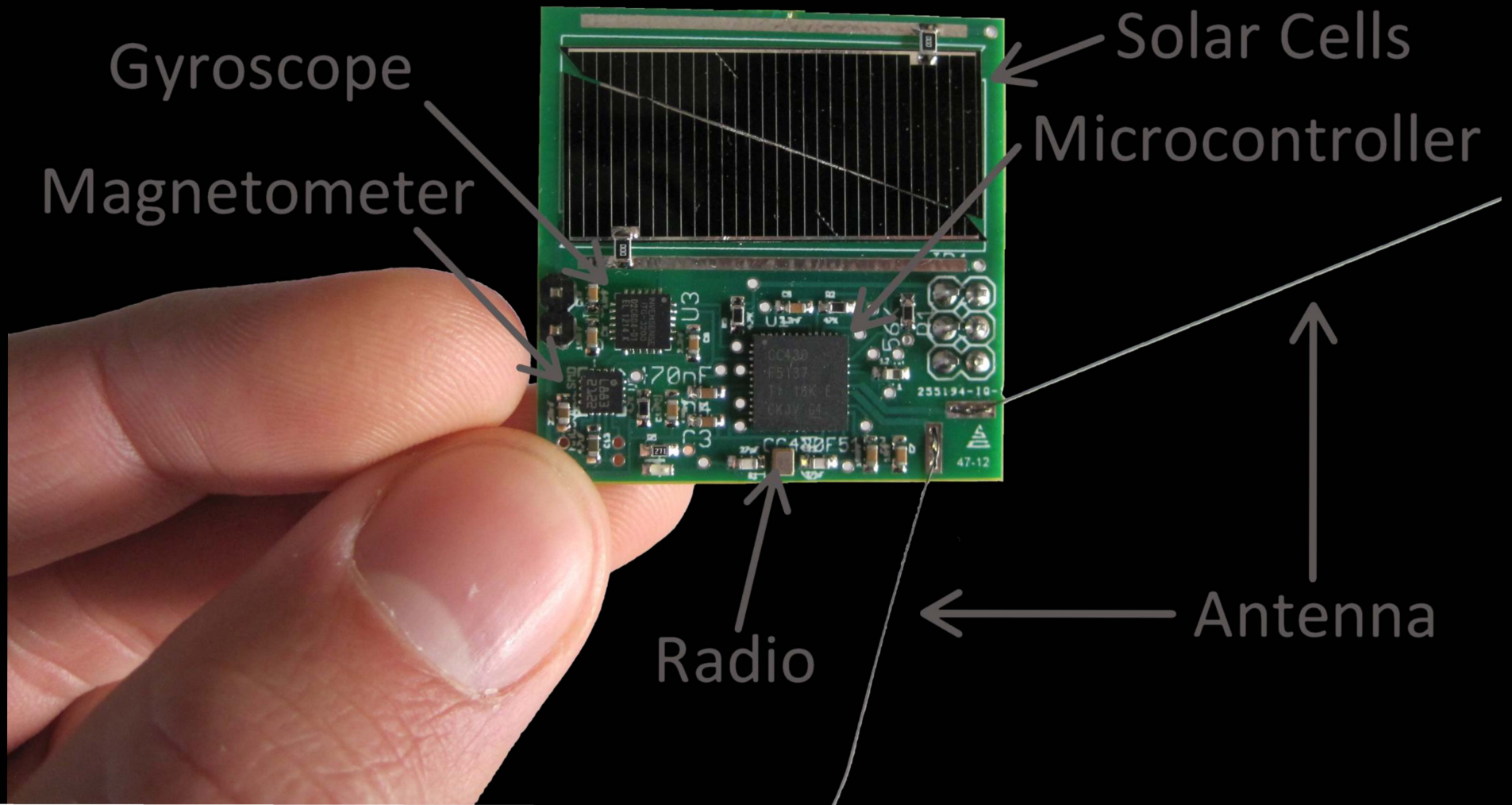
- Feel free to reach out to me:

david.mauro@nasa.gov


Questions & Open discussion

BONUS Material

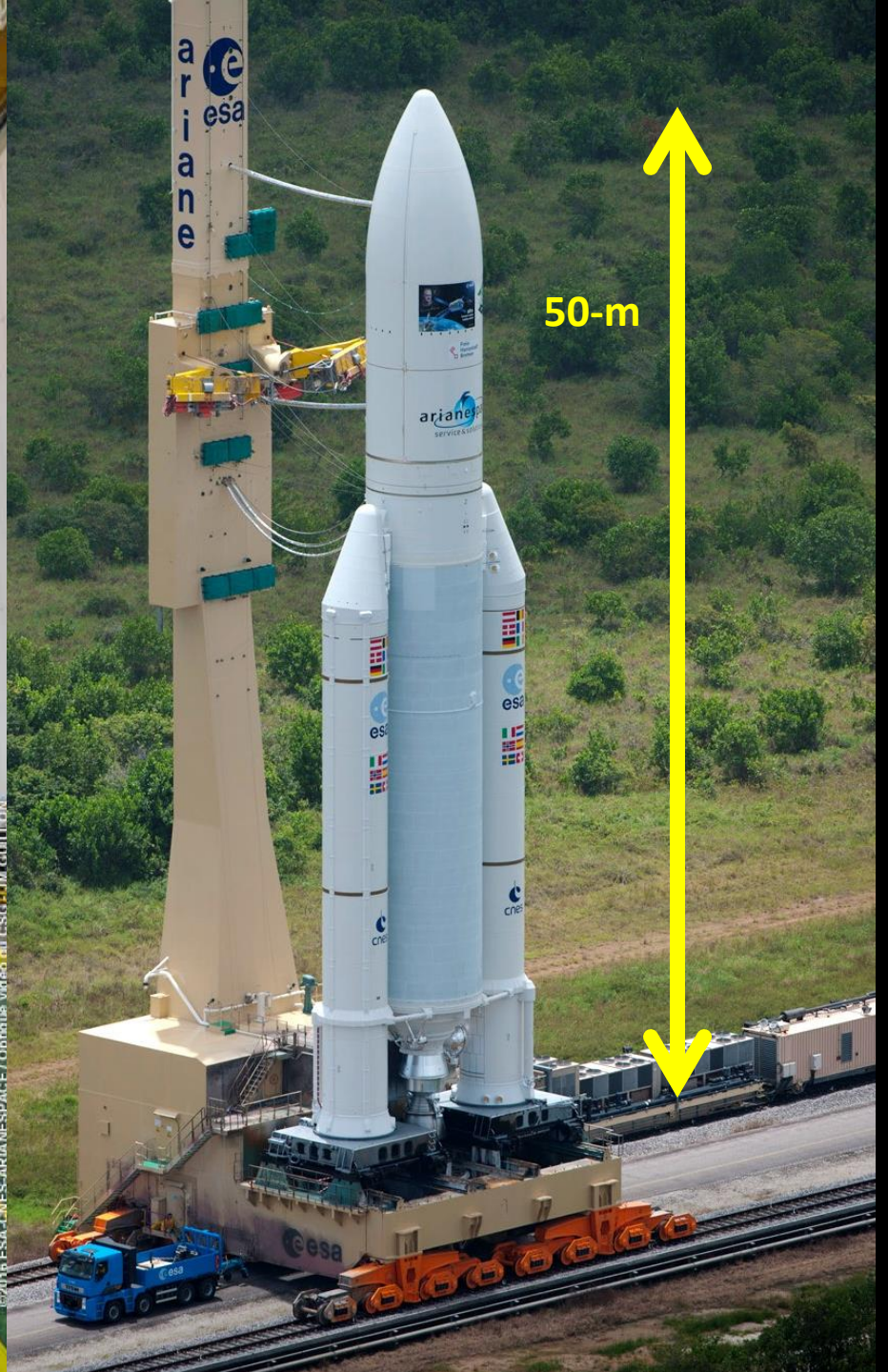

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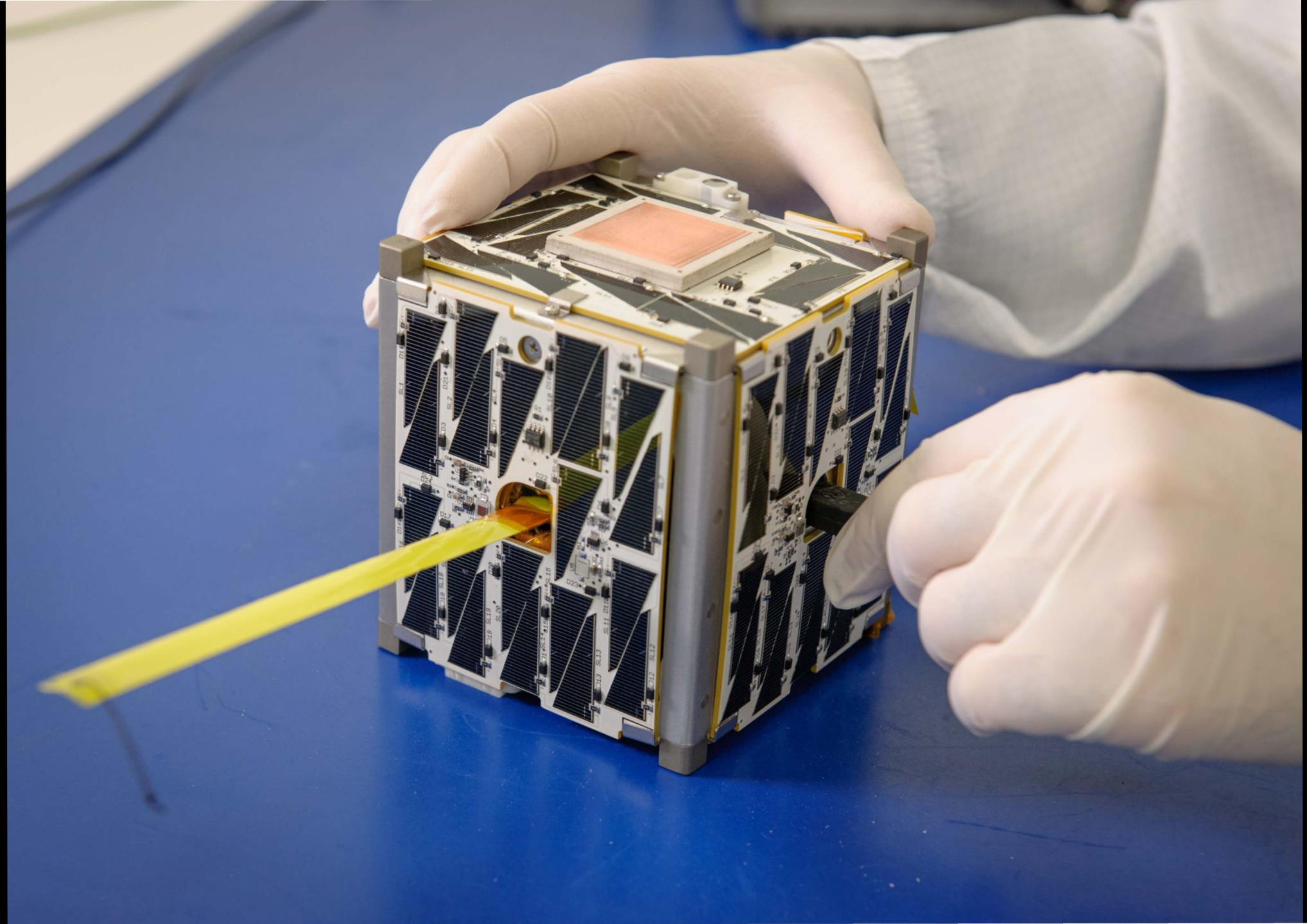

Gyroscope
Magnetometer
Solar Cells
Microcontroller
Antenna
Radio




STARS AND THEIR
WHEREWITH
THE SEA:··
MIX SCO
SSED BY M


eutel
ariane
service


ariane
esa
50-m



National Aeronautics and Space Administration

Nanosat Missions and Plans at NASA Ames

Supporting the Goals of Science Investigations, Technology Development, and Advanced Exploration Systems

2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019



GeneSat

NASA's first fully automated, self-contained biological spaceflight experiment on a satellite of its size. Demonstrated an integrated analytical fluidics card assembly to monitor genetic changes of *E. coli* bacteria.



PreSat

Served as a risk-reduction and technology demonstration mission for PharmaSat.



PharmaSat

Grew and characterized yeast (*S. cerevisiae*); tracked metabolic activity in 46 jewells. Demonstrated > 7 weeks biocompatibility - survival in stasis followed by growth.



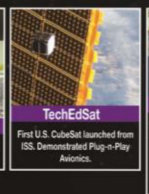
O/OREOS

Rehydrated, grew and characterized DRIED microbes (*B. subtilis*) in 36 fluidic wells. Demonstrated satellite bus and payload instrument functionality (> 2.5 years) and simultaneous C&DH.



PhoneSat 1b

First flight of a smartphone on a suborbital balloon test.



TechEdSat

First U.S. CubeSat launched from ISS. Demonstrated Plug-n-Play Avionics.



PhoneSat 1& 2β

Demonstrated that COTS reaction wheels and custom torque coils can work for low-cost Attitude Determination and Control System, and that TASC solar arrays charge batteries.



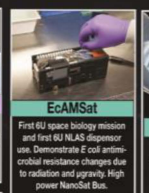
PhoneSat 2.5

Demonstrate that low-cost COTS ADCS works adequately in space; verify Google's Android™ processor can support space-based communications systems; demonstrate transmit of images to groundstation.



TechEdSat-4

Reflight of TechEdSat-3p Exobrake, with initial controllability for cross-range experiment. Improved iridium modems utilization.



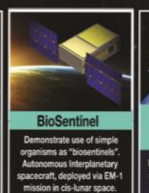
EcAMSat

First 6U space biology mission and first 6U NLAS dispensor use. Demonstrate *E coli* antimicrobial resistance changes due to radiation and μgravity. High power NanoSat Bus.



PowerCell

The PowerCell payload will investigate the performance of microbial mini-ecologies containing both photosynthetic microbes and consumer organisms. PowerCell is a payload on the DLR EuCROPIS CompactSat.



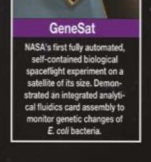
BioSentinel

Demonstrate use of simple organisms as "biosentinels". Autonomous interplanetary spacecraft, deployed via EM-1 mission in cis-lunar space.



Pathfinder Technology Demonstrator

Demonstrate and characterize novel small satellite technologies in low earth orbit.



NanoSail-D1

3U CubeSat to study the deployment of a solar sail in space.



NanoSail-D2

3U CubeSat to study the deployment of a solar sail in space - originally built as a ground spare for NanoSail-D1. Successful sail deployment.



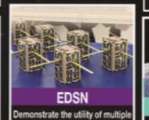
PhoneSat 2.4

Demonstrated that low-cost COTS ADCS works in space and that an Android™ processor works as S-Band command and telemetry modem. Demonstrated Nexus S long-term radiation survivability.



SporeSat

Demonstrate growth of organisms in gel medium. Update of Ames NanoSat Bus: processor, memory; Class B s/w.



EDSN

Demonstrate the utility of multiple small spacecraft working together in a cooperative manner. Cross link data on orbit between the satellite swarm and acquire simultaneous multipoint science data.



TechEdSat-5

Reflight of TechEdSat-4 Exobrake, with initial controllability for cross-range experiment. Improved iridium modems utilization.



Pathfinder Technology Demonstrator

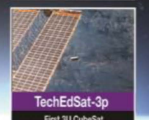
Demonstrate and characterize novel small satellite technologies in low earth orbit.



Pathfinder Technology Demonstrator

Demonstrate and characterize novel small satellite technologies in low earth orbit.





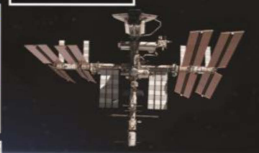
TechEdSat-3p

First 3U CubeSat launched from ISS. First sub-scale Exobrake test, iridium downlink/uplink, avionics/telemetry (TM) verification, and de-orbit.



NODeS

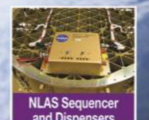
Extends EDSN capabilities to include command relay and negotiated control.





NLAS

Modular platform with configurable sequencing for deploying multiple secondary nanosats. Capability to deploy (8) 3U or (4) 6U or a combination up to 24U total.



NLAS Sequencer and Dispensers

Distributes 1 signal to 9 programmable outputs with the sequences reconfigurable via a GUI. Built-in software and hardware redundancies and is internally powered. Dispensers configurable to hold up to 24U.



SPHERES

Consists of 3 free flying satellites on board the ISS that test a diverse range of hardware and software.



ASTROBEE

Free-flying robot inside the Space Station for mobile sensing and 0g robotics tests. Launch NET Fall 2017.

NASA Ames

- **Achieves world-class Science with its Nanosat Missions**
- **Leads the development and flight of NASA Nanosat Systems**
- **Partners with Academia, Industry, and other Government Agencies including International Space Agencies on Nanosats**

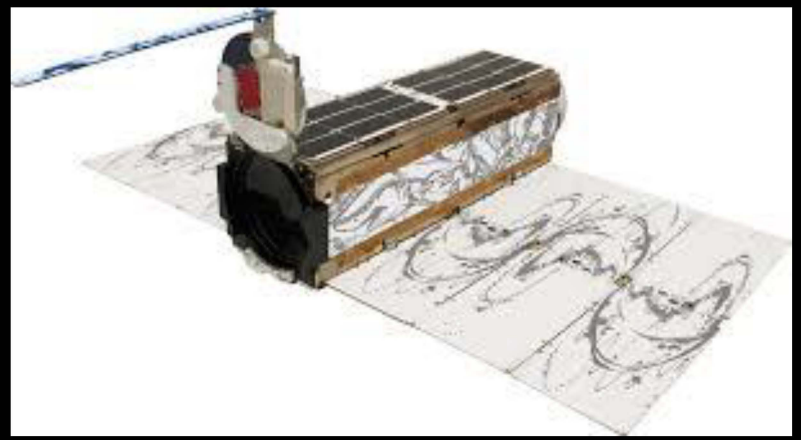
= Launched
= In development
= Future mission in formulation

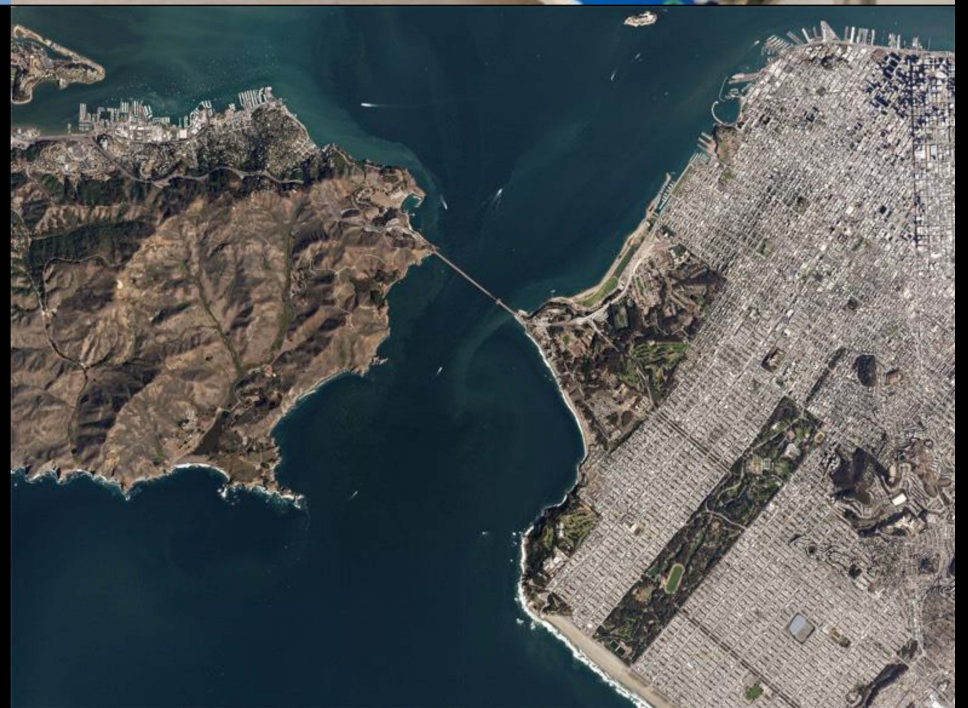
www.nasa.gov

www.nasa.gov/centers/ames/engineering



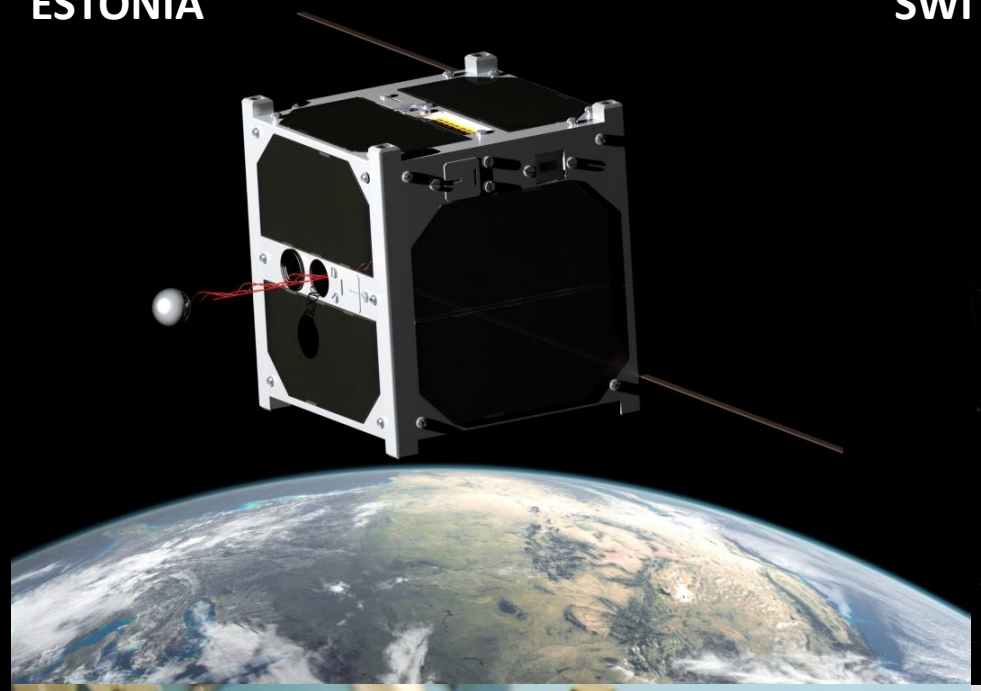

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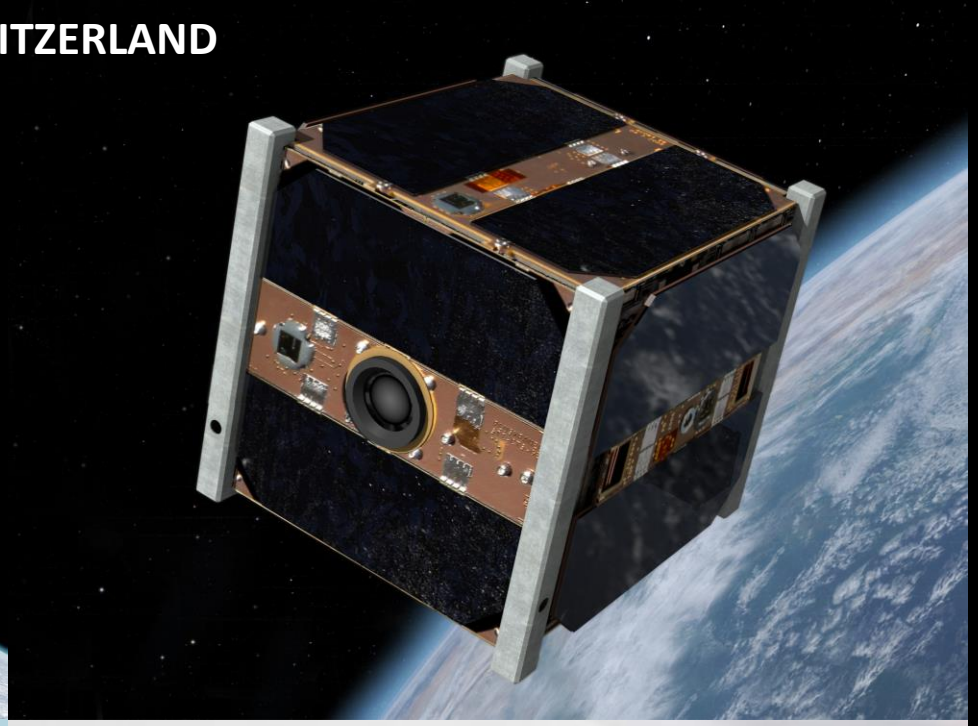




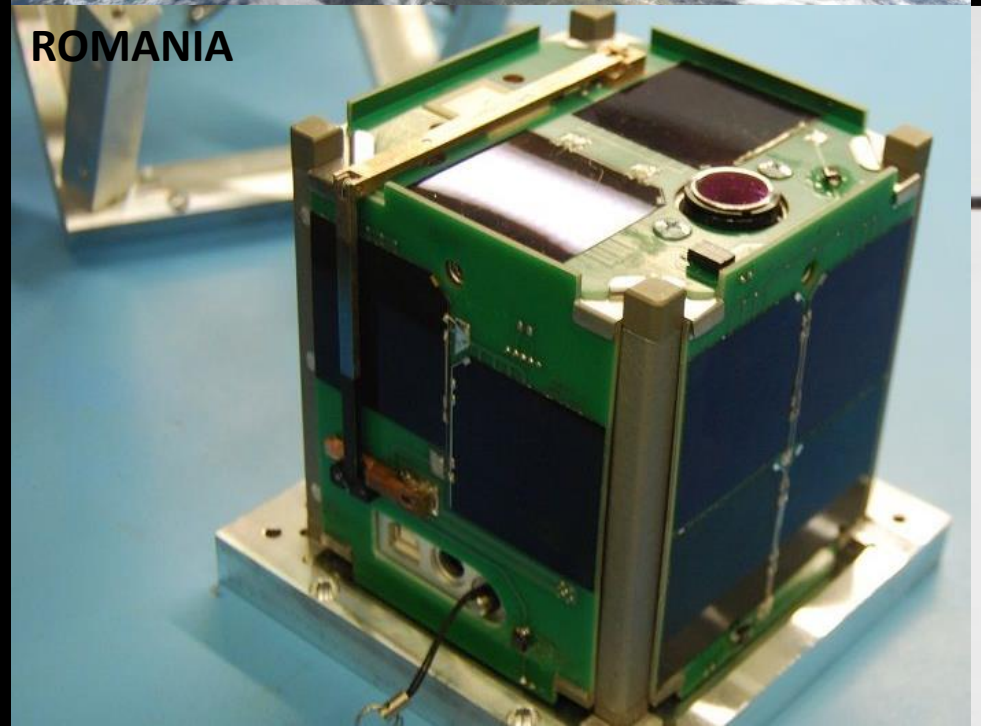
ESTONIA



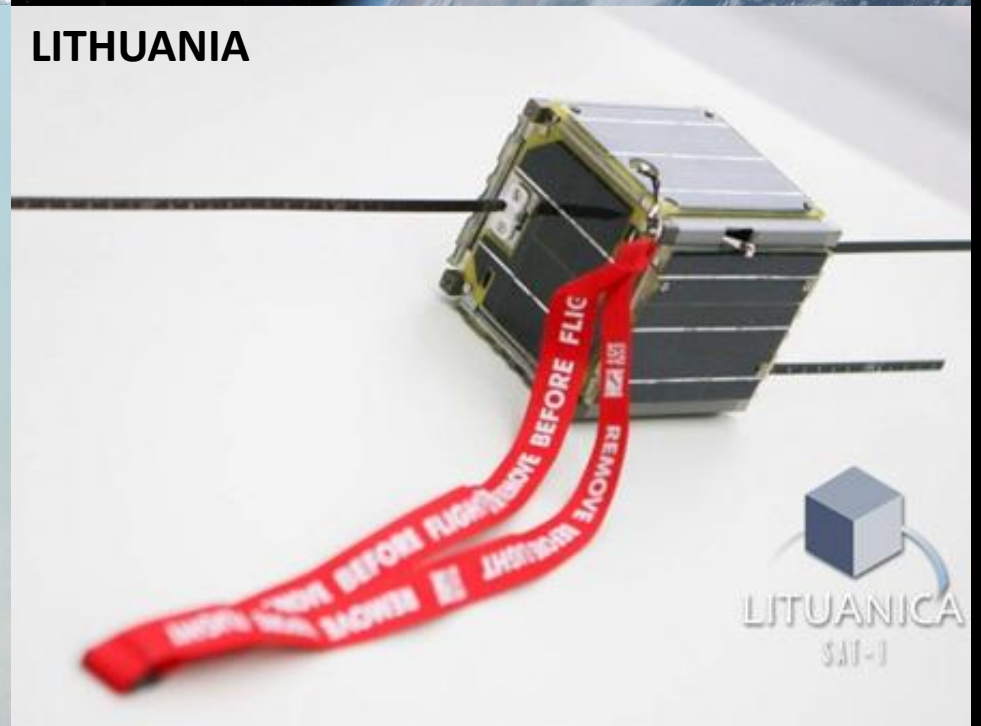
SWITZERLAND



ROMANIA



LITHUANIA



ROCKET LAB





7 At the end of this sequence, LauncherOne will deploy the on-board satellite into its orbit.



6 Typically, the second stage will burn multiple times for almost six minutes.

8 Both stages of LauncherOne will be safely deorbited, and the jet will return to the airport.

5 After stage separation, the single upper stage engine, called the 'NewtonFour' will carry the on-board satellite into orbit.



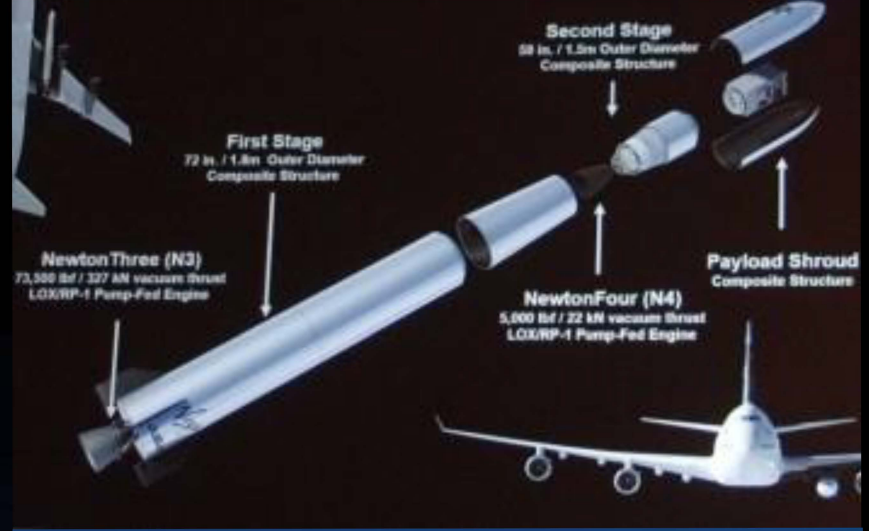
4 Once released, the rocket will fire up its single main stage engine called the 'Newton-Three' for three minutes.

1 The LauncherOne rocket will be mounted to the Boeing 747-400 under the left wing



2 By 'piggybacking' on the Boeing jet, it can be deployed from commercial airports

3 LauncherOne will be released at an altitude of approximately 35,000ft (10,668 metres).







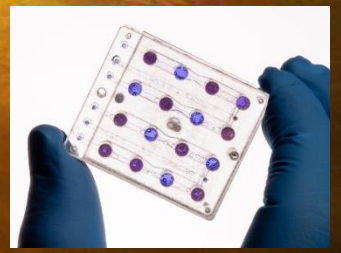


MarCO

Mars Cube One



BioSentinel









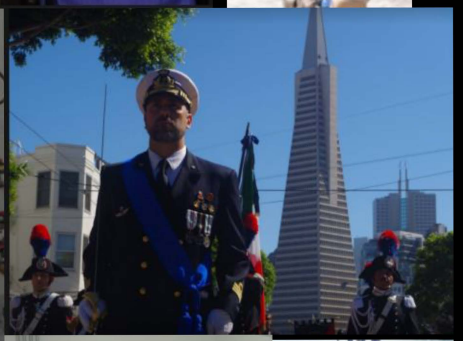





Small Satellite Communication technologies in support of the NASA Exploration Program
David MAURO
Master of Space Studies 09
27 August 2009




ENDLESS APPLICATION
SPORESAT






HONOR GRADUATE
Lt David Mauro



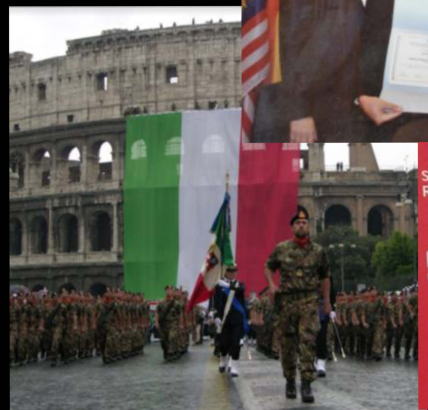













Strategic Decision and Risk Management






N4362P