Space Mission Concept Design

at the NASA Ames Mission Design Center (MDC)

Telecom with JAXA

4 February 2020

David Mauro, KBR / NASA Ames Research Center

Agenda

- Space Mission Concept Design at NASA Ames
  - What the Ames MDC is
  - A framework for space mission ideas – The Concept Maturity Levels
  - Aeolus: an example of a mission concept study for Mars
  - What's next
- Summary & Conclusion

Mission Design Center - What is it?

About the Mission Design Center

The Mission Design Center (MDC) is a facility within the Spaceflight Division that specializes in conceptual mission design. While experienced in multiple levels of design and mission implementation, the MDC focuses on low-cost, small spacecraft missions.

The MDC possesses full, end-to-end mission design capability with sophisticated analysis and simulation tools in a collaborative concurrent design environment. Services include:

- Concept Maturity Level (CML) progression
- Spacecraft design and trade studies
- Scientific instrument selection
- Feasibility assessments
- Proposal support and partnerships

These capabilities allow the MDC to support the Ames Engineering Directorate's ability to support all phases of engineering and project management for flight and mission projects from research and development to close-out.

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Examples of MDC-supported projects

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

2019

Luna Lynx

Preliminary feasibility assessment for a small spacecraft lunar communication relay with a Lunar South Pole asset.

Mission Concept Study report for the Dark Ages Polarimeter Pathfinder (DAPPER)

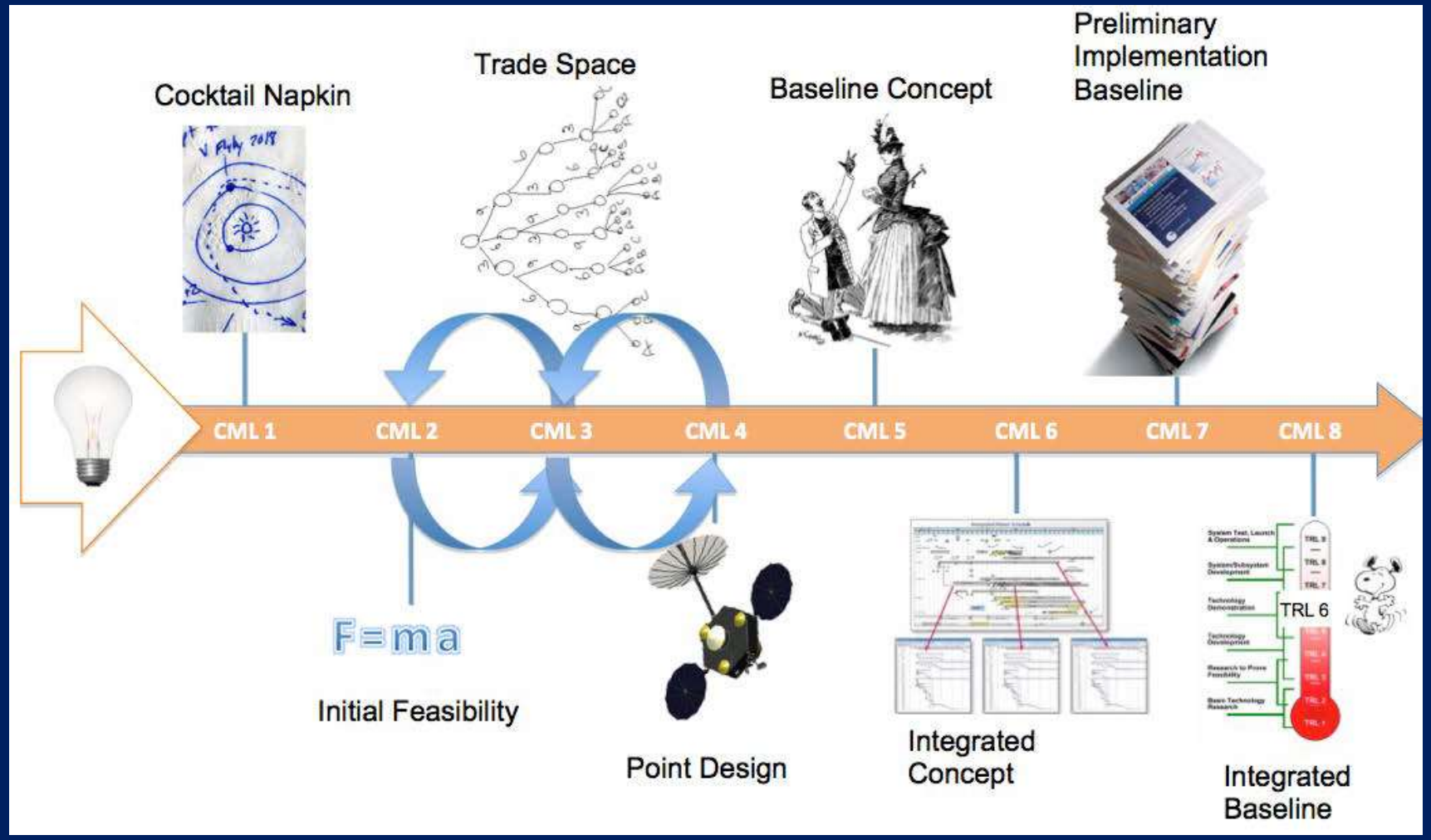
Mission concept study report designed to search for deviations from the standard cosmological model by measuring the global 21-cm spectrum.

Miniaturized Distributed Occulter Telescope (mDOT)

Mission concept study to provide unprecedented detection and direct measurements of brightness of extrasolar dust disks visible to ultraviolet wavelength using a small spacecraft starshade and a 6U telescope spacecraft. mDOT was selected as part of the Astrophysics Science SmallSat Studies solicitation.

https://www.nasa.gov/centers/ames/engineering/mission-design-center/about

A framework for space mission ideas
The Concept Maturity Levels



From: Space Mission Concept Development Using Concept Maturity Levels, Wessen et al., 2013

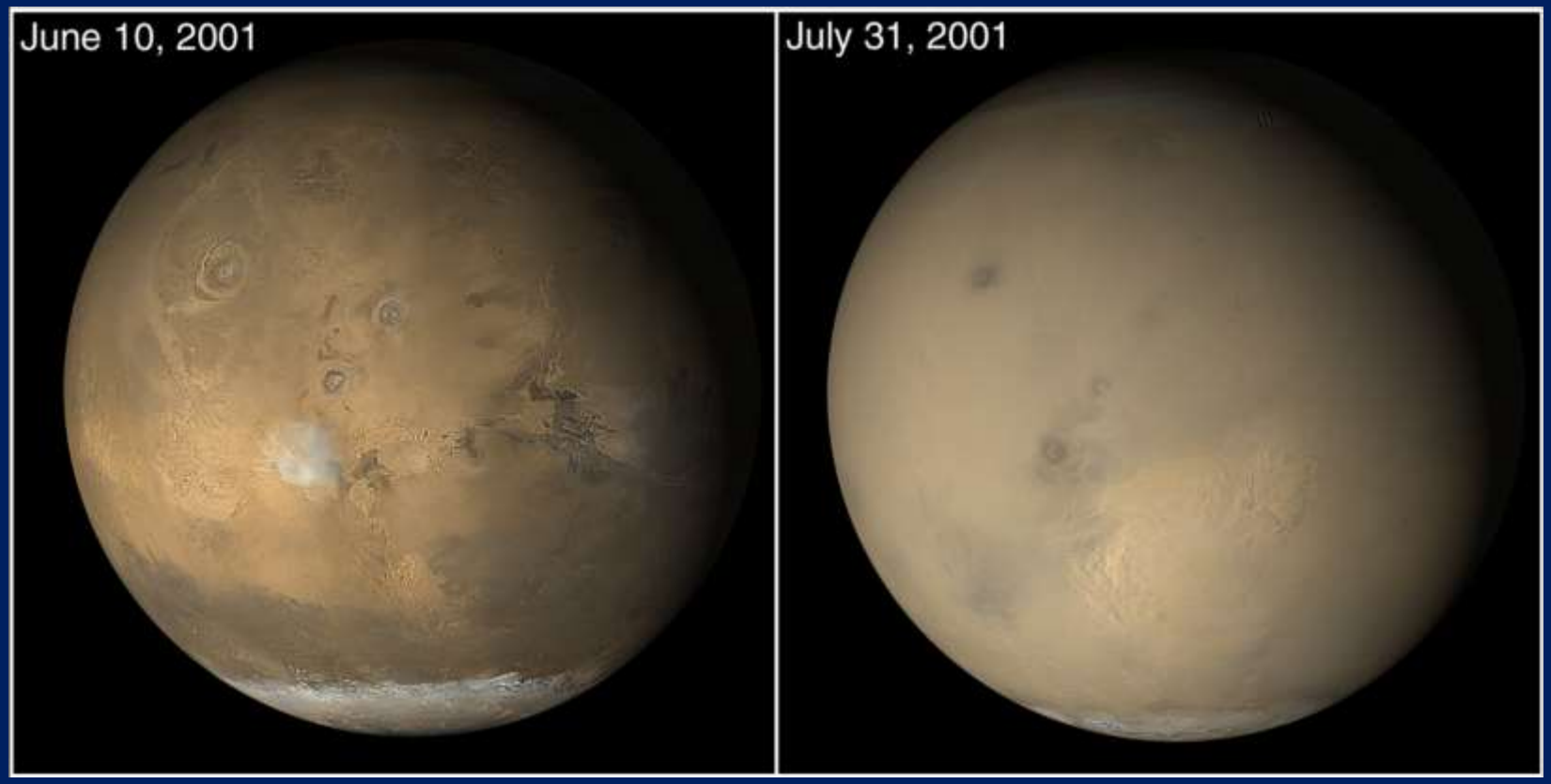
Aeolus: an example of a mission concept study for Mars

Aeolus: an example of a mission concept study for Mars

CML 1
“Cocktail Napkin”

Aeolus: an example of a mission concept study for Mars

CML 1
“Cocktail Napkin”

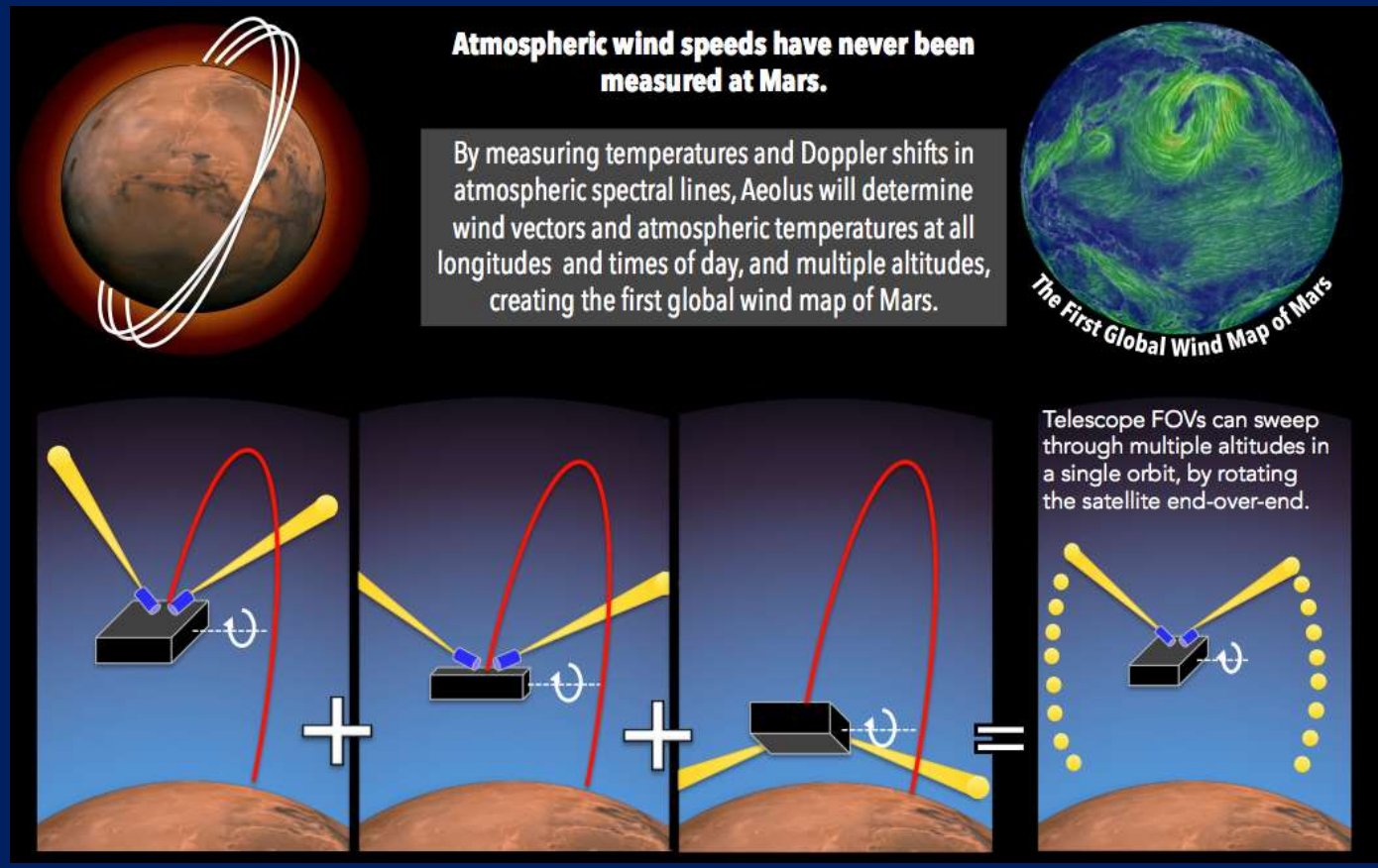


CML 1: Initial Cartoon

Meaningfulness & Uniqueness
Identify Knowledge Gaps

State Broad Science Objective

One-sentence description of measurement(s)



Aeolus: an example of a mission concept study for Mars

CML 1
“Cocktail Napkin”

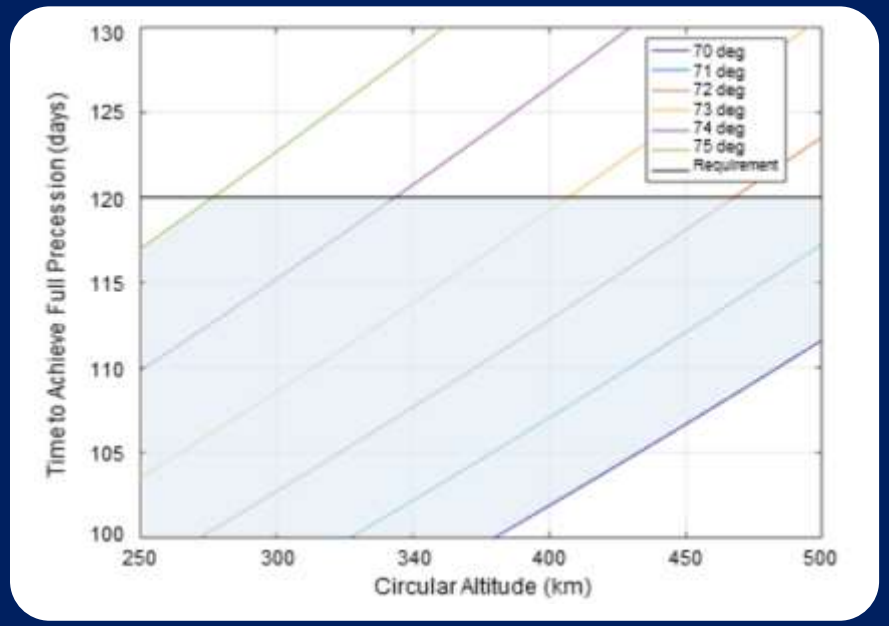
CML 2
Feasibility

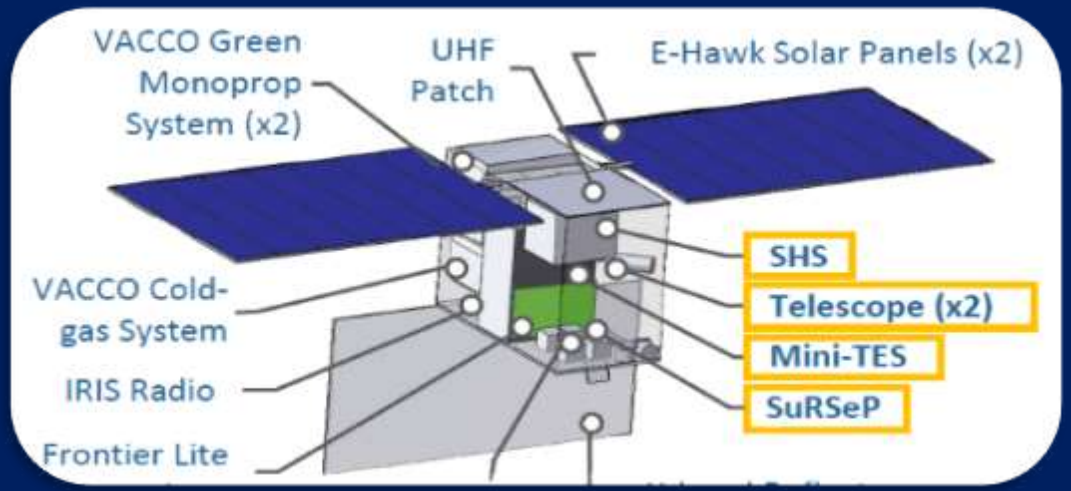
Does any solution exist?

CML 2: Feasibility Study

- Draft of Science Traceability Matrix
- Mission Architecture – main elements
  - Environmental driving parameters
  - Identify required tech development
  - Launch opportunities
  - Delta-V calculations
  - Orbital solutions
  - Mission ops
  - Spacecraft CAD model
- Rough cost estimate
- Rough schedule
- Initial risks & mitigation identified
- Future trades identified

Resource	CBE
Volume	45 x 35 x 52 cm
Total Launch Mass	37.6 kg
Total Power	53 W
Spacecraft Delta-V	237.5 m/s
Solid State Data Storage (Vol)	8GB
Data Throughput (UHF Downlink)	1Mbps





Aeolus: an example of a mission concept study for Mars

CML 1
"Cocktail Napkin"

CML 2
Feasibility

Does any solution exist?

CML 3
Expanded Trade Space

What other solutions exist?

CML 3: Expanded Trade Space

Divergent Phase:

Explore different mission architectures

primary vs. secondary

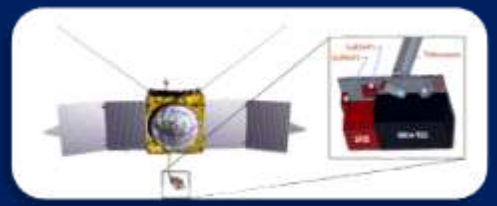
launch options

number of spacecrafts

et cetera

Convergent Phase:

Identify rejection criteria & pick architectures to pursue.



Iteration:

Repeat CML 2 as needed on selected architectures

Trade Dimensions	Tradable Options					
Mission Type	Primary	Secondary				
Approach Type	Flyby	Atmospheric Entry	Orbit	Landing on Phobos		
Measurement						
Surface	Lander	Rover	Impactor			
Atmospheric	Balloon	Dirigible	UAVs	long probe		
On-orbit	Single fixed	Single Variable	Swarm	Constellation		
Primary Power	Nuclear	Solar	Battery			
Drop-off	Earth	Helio	Outside Earth SOI	Intermediate Mars drop-off	Direct to final orbit	
Prop System	Solar sail	Solar EP	Chem	Nuclear EP		
Orbit Characteristics	Circular	Elliptical				
Periapsis/Altitude	Low Mars Orbit 200-600 km	~1000 km	≥17000 km			
Inclination	0 deg	1-60 deg	60-89 deg	90 deg		
Instruments	SHS	SURSeP	Mini-TES	Lidar	Imager	Radio (occultation)
Mass/Size	6U	12U	24U	ESPA (<180 kg)	>180 kg	
Science Pointing	rotating optics	Rotating SC	Imaging Array (fixed)	gimbaled instrument platform		
Ops and Data Return Technology	Direct to Earth	Relay				
Launch Vehicles/Options	Mars 2020	Mars 2022	EM-2	Dedicated		
Science Duration	3 Earth Months Full Surface Coverage (<1 Martian Season)	6 Earth Months 1 Martian Season	12 Earth Months 2 Martian Season	1.5 Earth Yrs 3 Martian Season	2 Earth Yrs 1 Martian Year (4 Martian Seasons)	4 Earth Yrs 2 Martian Yrs

LEGEND

- Elements selected in at least one architecture
- Technical rejection
- Science rejection
- Programmatic rejection
- Allowable but not selected (white), e.g. out of scope

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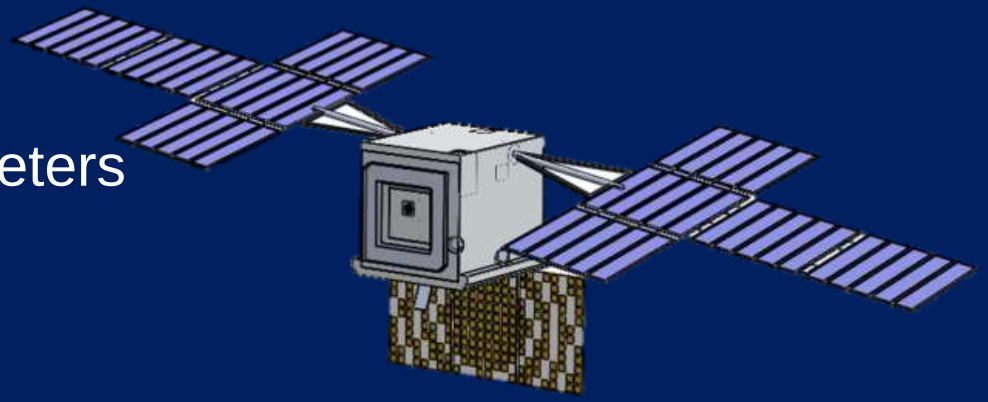
CML 4
Point Design

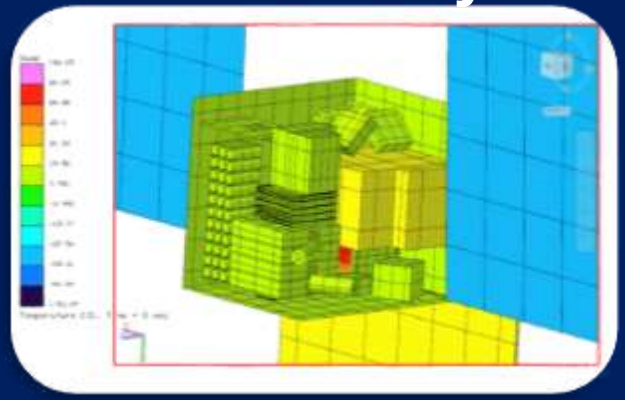
What is a good approach, given our circumstances?

CML 4: Point Design

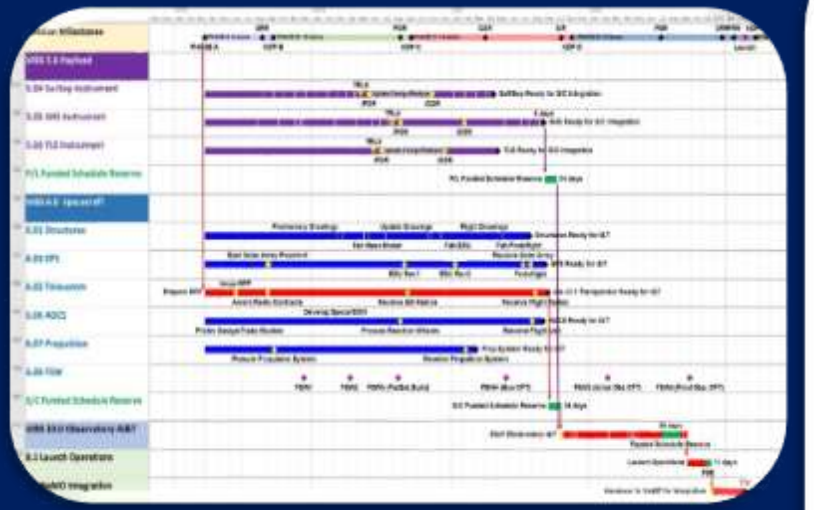
- Science Traceability Matrix
- Mission Architecture
  - Driving environmental parameters
  - Launch vehicle
  - Delta-V calculations
  - Orbital solution
  - Radiation Analysis
  - Mission ops
  - Identify required tech development
  - Spacecraft CAD model
  - Power Analysis
  - Thermal Analysis
- Better Cost Estimate
- Refined Schedule
- Risks Matrix & Mitigation



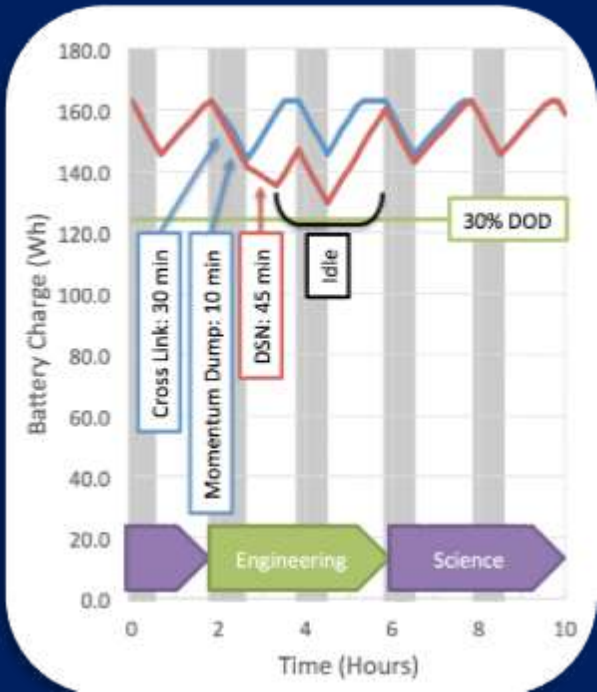
Thermal analysis



Schedule



Power analysis



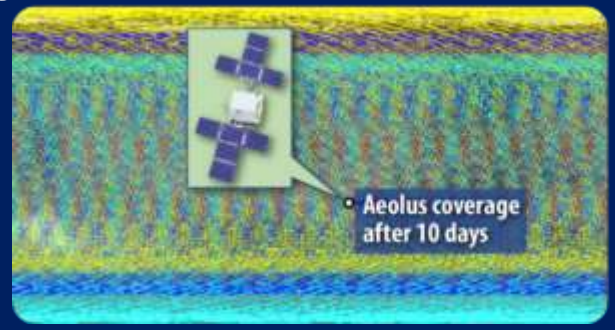
CML 4: Point Design

Science Traceability Matrix
Mission Architecture
- Driving environmental parameters
- Launch vehicle
- Delta-V calculations
- Orbital solution
- Radiation Analysis
- Mission ops
- Identify required tech development
- Spacecraft CAD model
- Power Analysis
- Thermal Analysis

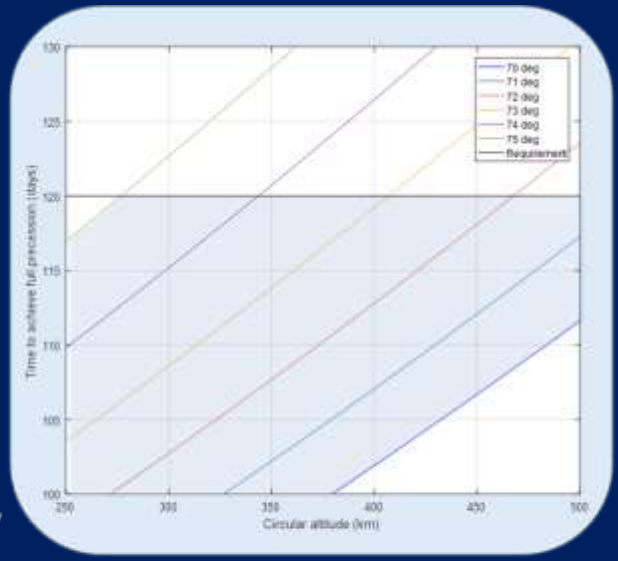
Better Cost Estimate
Refined Schedule
Risks Matrix & Mitigation

Refined orbit design

Orbit precesses over all *local times* within 2 months



Global spatial coverage every 10 days

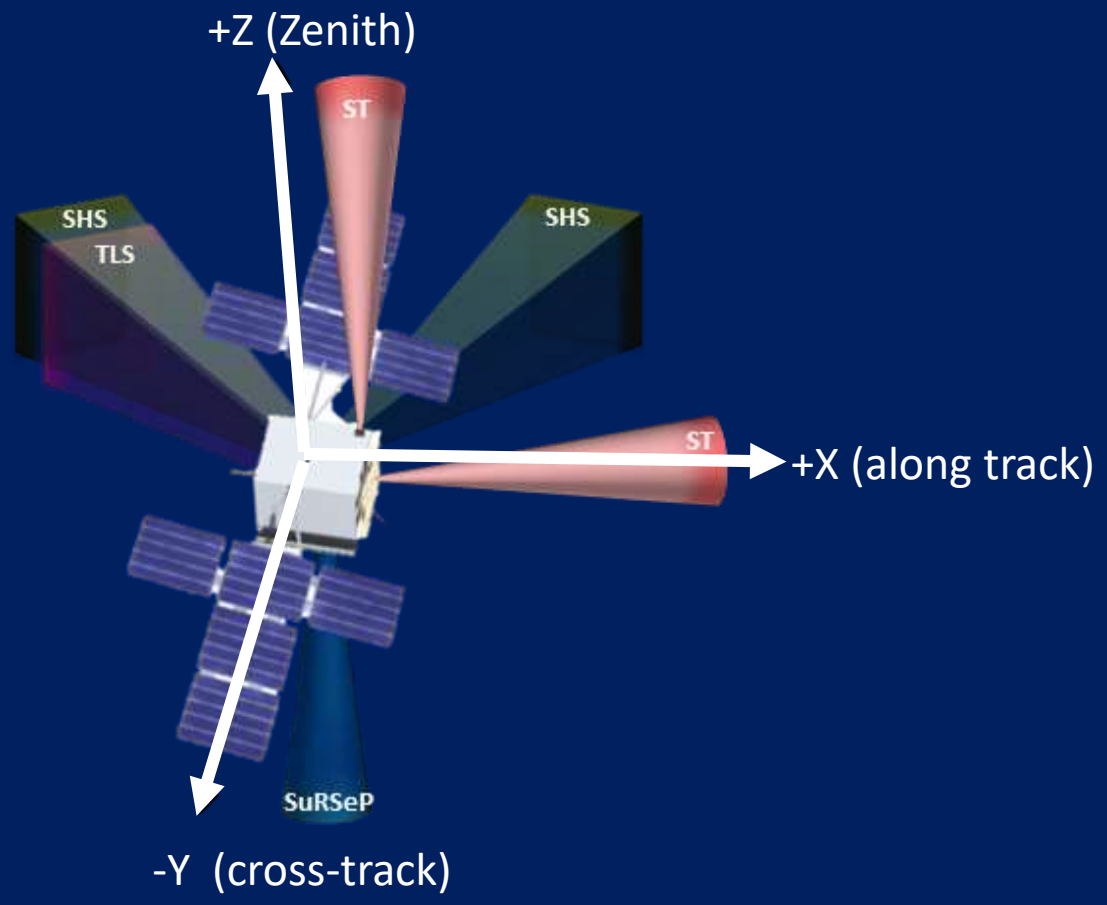


CML 4: Point Design

Science Traceability Matrix
Mission Architecture
- Driving environmental parameters
- Launch vehicle
- Delta-V calculations
- Orbital solution
- Radiation Analysis
- Mission ops
- Identify required tech development
- Spacecraft CAD model
- Power Analysis
- Thermal Analysis

Better Cost Estimate
Refined Schedule
Risks Matrix & Mitigation

Refined Flight system capabilities

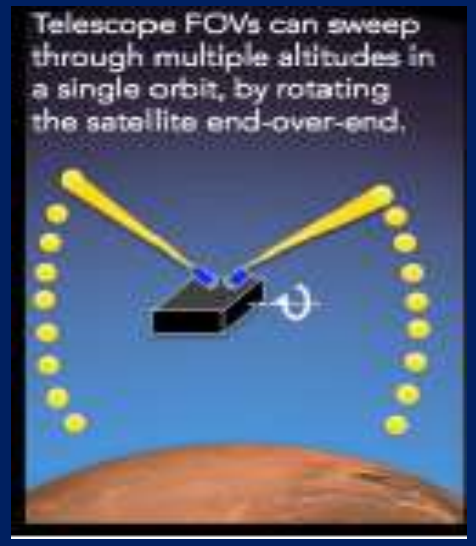


Maturation of a Concept from CML 1 to CML 4

CML 4

CML 2

CML 1



What's Next

- Updating Concurrent Engineering Tool
- New Training for Personnel involved in MDC studies
- Integration of a Parametric Cost Tool into the Concurrent Engineering Tool
- Improvement of Methodology and Processes

Summary & Conclusion

- NASA Ames MDC uses the CML framework for Mission Concept Studies
- MDC focuses on CML 1 to 4
- Technical focus is on small (up to ~ 200 kg) spacecraft platforms, both Earth orbiting and deep space
- Highly integrated with Ames Flight Dynamic team
- Current focus is on improving current Concurrent Engineering capabilities

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