2020 Astrophysical Decadal Survey

Probe Studies Kickoff Meeting

2017 May 19

Kickoff Meeting Agenda

2017 May 19, 2:00 to 4:00 pm EDT

START TIME	TOPIC	PRESENTER
2:00	PROCESS AND MANAGEMENT - HQ PERSPECTIVE	Rita / Shahid
	• **PURPOSE** • **PROBES STUDIES FUNDING:** Start and End dates; No-cost Extensions; Fund Phasing • **OVERSIGHT AND REPORTING:** Quarterly Reports; Winter 2018 AAS presentation	
2:20	CONCURRENT DESIGN LABS	Kelley / Jennifer
	• **TEAM-X PRESENTATION:** Process, Products, etc. • **IDC PRESENTATION:** Process, Products, etc.	
2:50	ENGINEERING	Keith / Gabe
	• **DESIGN GUIDELINES:** Contingencies and Margins; Rules of Thumb • **FINAL DELIVERABLE:** Definition of the Contents; Page Limits	
3:10	TECHNOLOGY	Rita / Shahid
	• **TECHNOLOGY MATURATION**	
3:20	COST	Cindy Daniels
	• **INDEPENDENT COST ESTIMATE:** TMC Process	
3:40	QUESTIONS AND ANSWERS	All Participants
	• **OPEN DISCUSSION**	
4:00	ADJOURN	

Probes Studies Management and Process

Overview

Rita Sambruna, Probe Studies Program Scientist
Shahid Habib, Probe Studies Program Executive
Astrophysics Division, NASA Headquarters

May 19, 2017

Outline

- Purpose
- Funding process for the Probes studies
  - Start and End dates
  - No-cost Extensions
  - Fund Phasing
- Oversight Approach and Reporting
  - Quarterly report
  - Winter 2018 AAS presentation

Purpose

- NASA is preparing these studies for the decadal committee use
- Studies are chartered by NASA and the PI is responsible to provide the final product (written report) to NASA
- NASA will submit these studies to the Decadal Committee
- The Decadal will have the option to prioritize any of these mission concepts, or recommend a competed line of Probes (similar to Explorers)
- Selections will be based on science merit

Astrophysics Division

Selected Probe Mission Concept Studies

PI	Affiliation	Short title	Design Lab/Prog Office
Camp, J.	NASA's GSFC	Transient Astrophysics Probe	IDC/PCOS-COR
Cooray, A.	Univ. California, Irvine	Cosmic Dawn Intensity Mapper	TeamX/ExEP
Danchi, W.	GSFC	Cosmic Evolution through UV spectroscopy	IDC/PCOS-COR
Glenn, J.	Univ. of Colorado	Galaxy Evolution Probe	TeamX/ExEP
Hanany, S.	Univ. of Minnesota	Inflation Probe Mission Concept Study	TeamX/ExEP
Mushotzky, R.	Univ. of Maryland	High Spatial Resolution X-ray Probe	IDC/PCOS-COR
Olinto, A.	Univ. of Chicago	Multi-Messenger Astrophysics	IDC/PCOS-COR
Plavchan, P.	Missouri State Univ.	Precise Radial Velocity Observatory	No design lab funded/HQ grant
Ray, P.	Naval Research Lab	X-ray Timing and Spectroscopy	IDC/PCOS-COR
Seager, S.	MIT	Starshade Rendezvous	TeamX/ExEP

Points of Contact (POCs) for the study Teams:

- G. Karpati, PCOS/COR
- K. Warfield, ExEP

Funding and Extensions

- NASA supports the selected Probe Studies via awards to the PIs' Institutions to conduct an 18-month study. As specified in the PI package distributed earlier, the assigned Points of Contact (POCs) at GSFC and JPL will be monitoring expenditures and reporting to HQ
- NASA supports the PI design lab of choice (either TeamX or IDC) to perform design lab runs. Each study will get **one** run at their Lab of choice supported by NASA. PIs are free to arrange for additional runs at no additional cost to NASA, conditional on availability of labs
- Funds phasing:
  - PI awards: first 6 months of the study were released in April 2017. In FY18, the remaining balance will be awarded. Your award package provides a starting date for the period of performance. The clock starts ticking then.
  - The duration of of the NASA-supported study is 18 months.
  - Design Lab: funding is disbursed directly to the Labs by HQ
- **No-cost extensions**: if needed, the Teams can ask HQ for an extension of the study period for a few months, but no additional funds will be awarded by NASA for the additional months beyond the 18 months baseline.
  - The final report is due to NASA no later than December 31, 2018. Duration of the no-cost extension needs to meet this deadline.

HQ Oversight

- HQ has delegated the day-to-day oversight activities to the POCs listed on slide 4. See Appendix A for a description of their functions.
- HQ will maintain oversight of the studies through the POCs who report to HQ regularly.
- The Study PIs will provide a quarterly report to their POC with a description of the status of the study. Use template in the next slide for the quarterly report.
  - Reports are due to the POCs by (for a nominal duration of 18 months):
    - 2017: August 1, November 1
    - 2018: February 1, May 1, August 1, November 1
  - Additional reports as needed during no-cost extensions

PROBE TITLE

PI's name/Organization
Date

Science / Observations / Measurements:
- Brief description of science goals/objectives

Mission Overview:
- Brief description of orbit, launch, mission life, and conops

Flight System:
- < Brief description of the spacecraft, telescope, instruments, etc.>

Any picture the PI chooses
(illustration, photo, block diagram, chart, or table, of recent work)

Preferably changing with every submission

Recent Accomplishments:
- Key accomplishment 1
- Key accomplishment 2
- …

Study Budget

< Bar chart budget by quarter along with actual spending by quarter>

Next Milestones:
- Milestone or Accomplishment w/ est. completion date
- Milestone or Accomplishment w/ est. completion date
- …

Issues, Concerns:
- Issue or Concern 1
- Issue or Concern 2
- …

Probe session at the winter 2018 AAS

- NASA is organizing two back-to-back special sessions at the winter 2018 AAS meeting for the Decadal studies, to inform the astrophysics community of the progress achieved thus far in all NASA-sponsored studies:
  - Morning session: Large Scale Studies
  - Afternoon session: Probes studies
- Special sessions have an allocation of 90 minutes
- Each Probe study will have ~10 minutes (including questions) to present the status of the Study, including: science case, activities to date, noteworthy results so far, announcements for workshops, future steps
- NASA does **<u>not</u>** expect that at the time of the 2018 AAS meeting the mission design labs will be completed for the purpose of the presentation, nor that cost estimates will be defined.
- Question to PIs: Should NASA arrange for an adjunct Probes poster session as well?

Final report

- A written final report is due at the end of the 18-months study (or no-cost extension) and **no later than** December 31, 2018. Submit your report to the Point of Contact, who will then forward to HQ.
- The Teams are free to choose their format for the written report. See upcoming presentation for suggested guidelines.
- No more than 50 pages.
- HQ will add the ICE reports from TMC and deliver the complete reports to the Decadal Committee.

Astrophysics Division

Appendix A: POCs roles and functions

(from the PI package)

- Responsible for communication with the PI study teams to ensure consistent and complete information is provided to all
- Develop an integrated plan for the multiple studies in the Design Lab and broker the dates and durations for each study with the PIs and the Labs (before April 30, 2017).
- Collect quarterly status from and monitor progress of the PI study teams. Convey status and progress on all studies to HQ
- Assist the PI in the definition of and preparation for the Design Lab studies. The PO will support the study runs in the Design Labs. The PO may suggest synergies between the studies to take advantage of commonalities of designs/requirements and economize the design lab expenditures. PIs have the prerogative not to accept the PO recommendations
- Monitor the expenditure of funds at the Design Labs and report regularly to HQ
- Organize teleconferences with all the selected Teams to facilitate synergies and cross pollination of ideas.
- Produce an integrated Executive Summary report of all studies summarizing salient features and costs and deliver to HQ

Team X Overview for Astrophysics Probe Studies

Kelley Case
Concept Design Methods Chief
JPL Office of Formulation

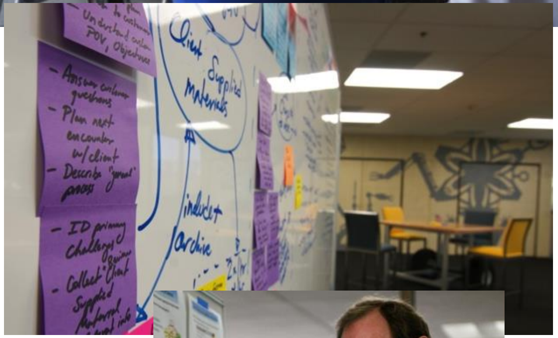
May 19, 2017

Challenge for Probe Studies

- Deliver Compelling Science with a Credible Cost
- Provide a report to NASA HQ for input into the NRC Decadal Survey

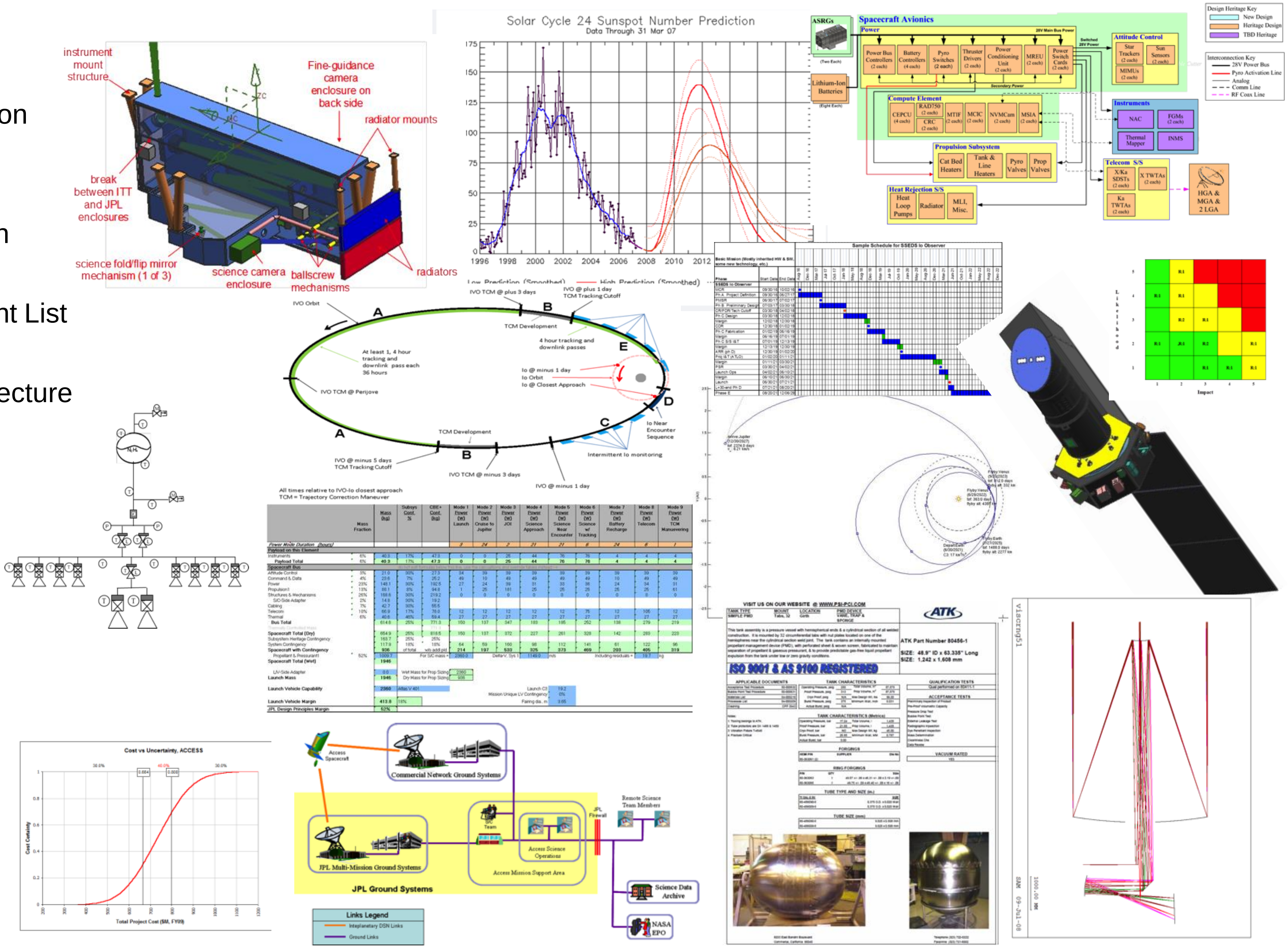
Team X Methods & Services

- Team X offers different methods and services depending on the level of the concept maturity
  - Science Workshops
  - Instrument Design and Sensitivity
  - Mission Concept Design
    - Real-Time Engineering Trades
    - Cost Estimation
- Team X provides…
  - Facilitated Design Studies
  - Access to subject-matter experts (technical and programmatic)
- Team X Final Report for all studies
  - Includes Point design description, MEL/PEL, Configuration, Cost Estimate (parametric models)



Team X Products

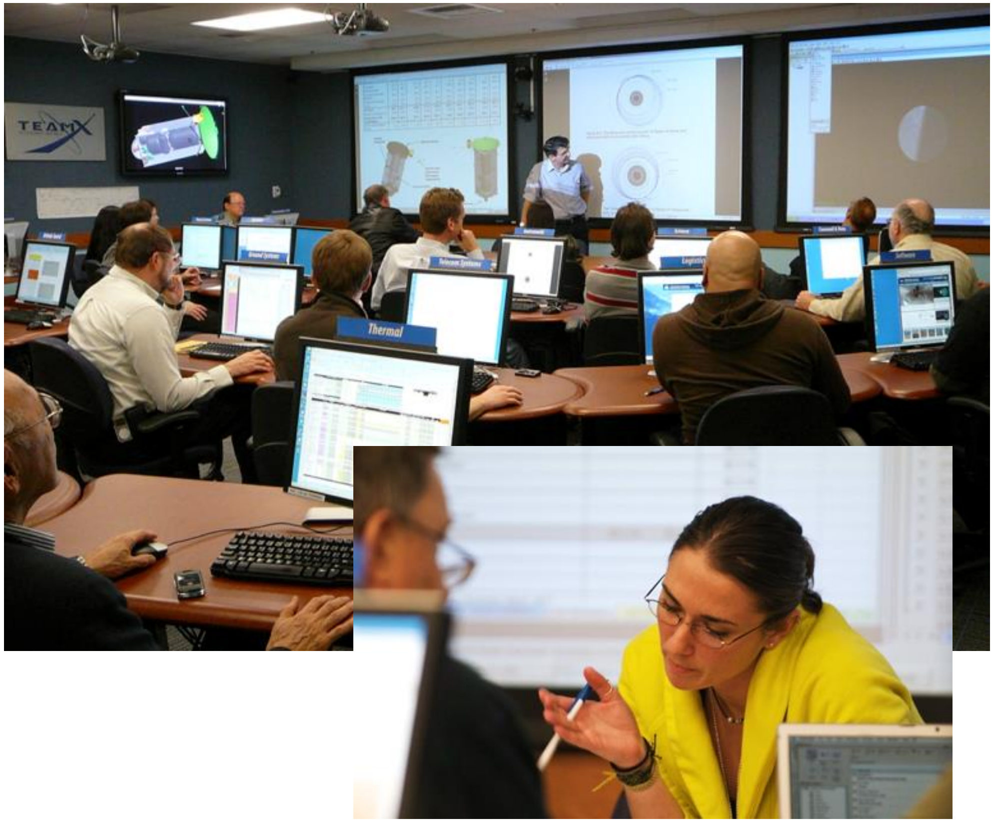
- Instrument Design
- Point Design Description
- Thermal FEA
- Observing Strategies
- Trajectory/Orbit Design
- Optics Ray Tracing
- Mass/Power Equipment List
- Block Diagrams
- Ground System Architecture
- Operations Scenarios
- Data Volume/Rates
- Downlink Budgets
- CAD
- Parts Lists
- Heritage Descriptions
- Radiation Analysis
- Schedule Estimates
- Cost Estimates
- Cost Risk S-Curves
- Risk Lists/Matrix
- Design Trades



Team X Overview

- Team X is JPL’s 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
  - Supported the 2010 Astronomy and Astrophysics Decadal Survey



Schedule and Planning Studies

- In May/June timeframe hold Client meetings with each Study team (PI, Study Lead, and others as needed) to discuss a study plan
  - Schedule the number and types of studies and select study dates

- Study Timeline
  - 2-3 weeks prior to study hold a one-hour Planning Meeting
  - 1-2 weeks prior to study hold a one-hour Pre-Session Meeting
  - Design Study (usually 2 to 4 half-day sessions)
  - ~ 2 weeks post study Team X to deliver a Draft Team X Report
  - ~ 3 weeks post study Team X to deliver a Final Team X Report

JPL Team X Contact Information

- Concept Design Methods Chief

  Kelley Case

  Kelley.E.Case@jpl.nasa.gov

  818-354-5870

- Team X Lead Engineer

  Alfred Nash

  Alfred.E.Nash@jpl.nasa.gov

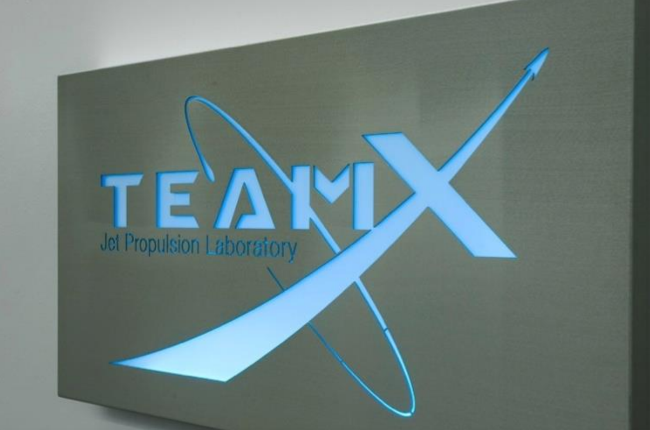
  818-393-2639

- Team X Administrator

  Melissa Brown

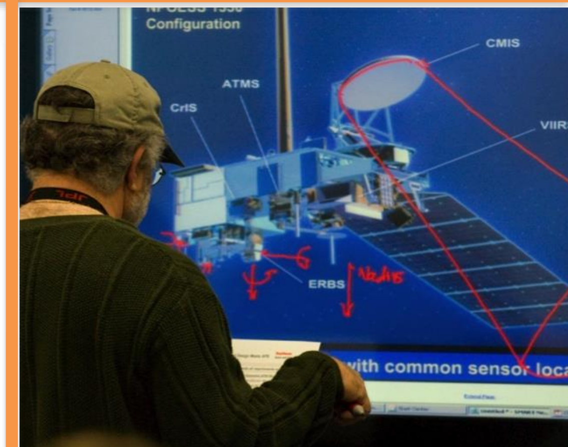
  Melissa.Brown@jpl.nasa.gov

  818-393-7383


TEAM X
Jet Propulsion Laboratory

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

Questions?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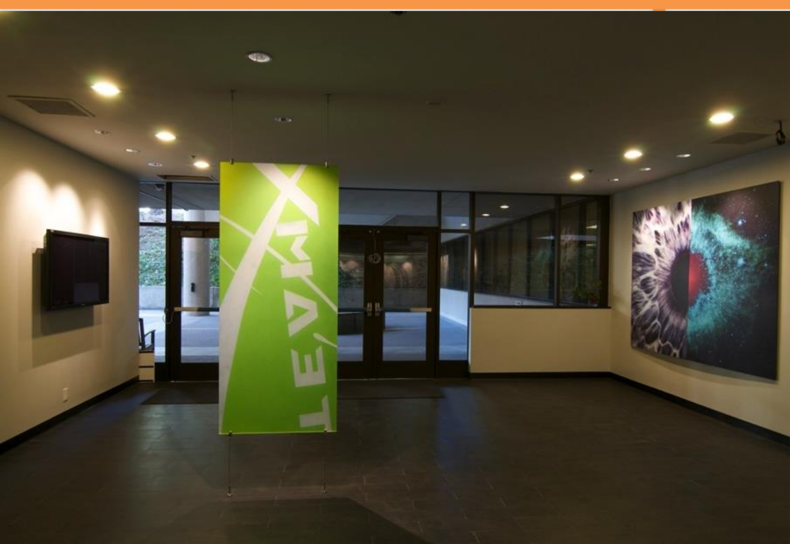
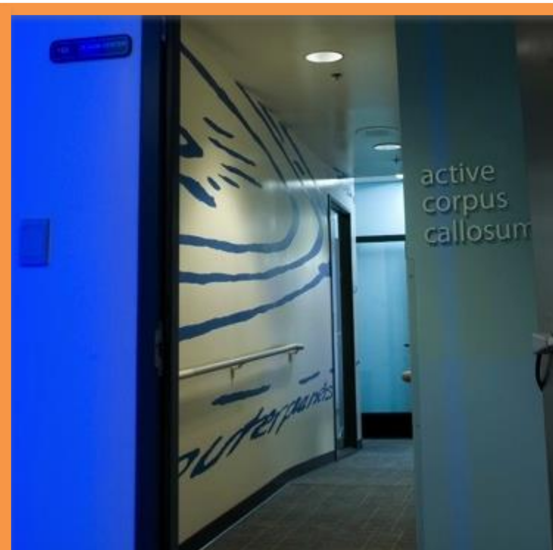
ERBS

TEAM X

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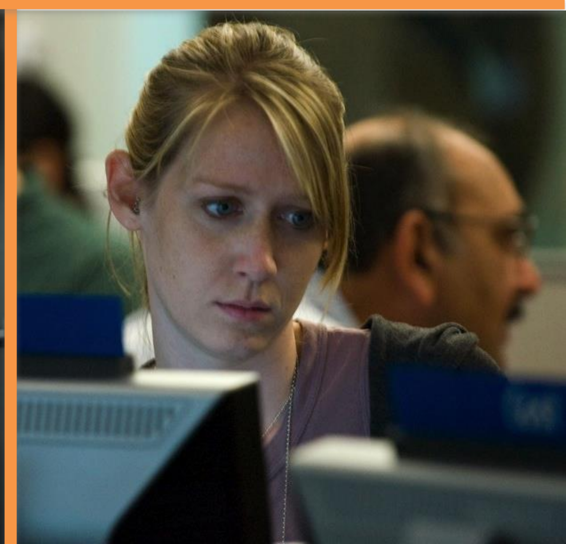


Overview of the GSFC Integrated Design Center (IDC)

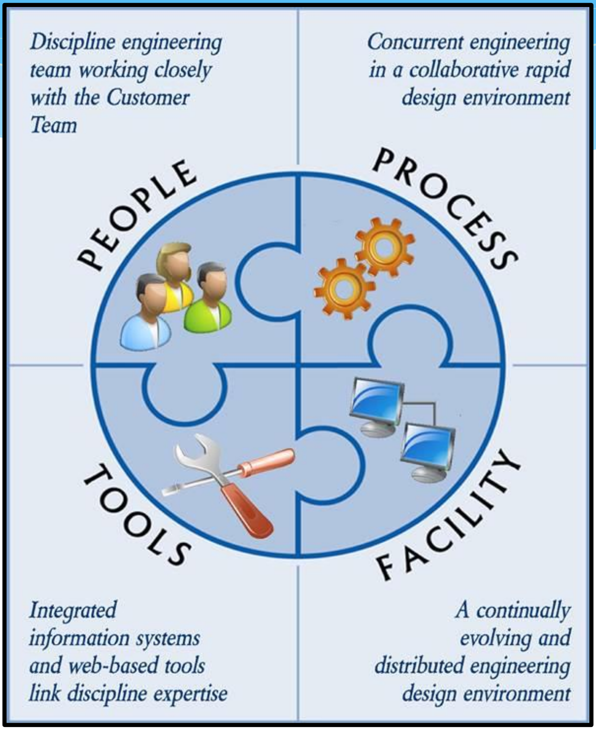
Astrophysics 2020 Decadal Probe Class Kickoff

Yesterday's dream, today's concept, tomorrow's reality.

Jennifer Medlin Bracken
IDC Manager
301-286-5127
Jennifer.M.Bracken@nasa.gov

Integrated Design Center (IDC)

An environment that facilitates multi-disciplinary, concurrent, collaborative, space system engineering design and analysis activities,



to enable rapid development of science instrumentation, mission, and mission architecture concepts.

IDC Inception and Evolution

Mission Design Lab (MDL)
- Created in 1997
- Initially known as the Integrated Mission Design Center (IMDC)

385 completed studies

Instrument Design Lab (IDL)
- Created in 1999
- Initially known as the Instrument Synthesis & Analysis Laboratory (ISAL)

259 completed studies

Architecture Design Lab (ADL)
- Created in 2012
- Filled need for additional flexibility with broad types of architecture studies

33 completed studies

Integrated Design Center (IDC)
- Created in 2001
- Initially known as the Integrated Design Capability (IDC)

Grand total: 677 completed studies

People

Mission Design Lab (MDL/ADLm)

Lab Lead | **MDL Systems Engineers**

- Mission Cost 158
- Reliability 371
- Structural 542
- Mechanical Systems 543
- Thermal 545
- Contamination 546
- Mechanical Designer 547
- Radiation Environment 561
- Power Systems 563
- Avionics 565
- Communications 566/567
- Integration and Test 568

- Mission Operations 581
- Flight Software 582
- Ground Systems 583
- Attitude Control 591
- Orbital Debris 592
- Planetary Protection 592
- Flight Dynamics 595
- Team Lead 599
- Mission Systems Engineer 599
- Launch Vehicle 599
- Propulsion 597

Experienced, knowledgeable engineers available for all required disciplines.

Instrument Design Lab (IDL/ADLi)

Lab Leads | **IDL Systems Engineers**

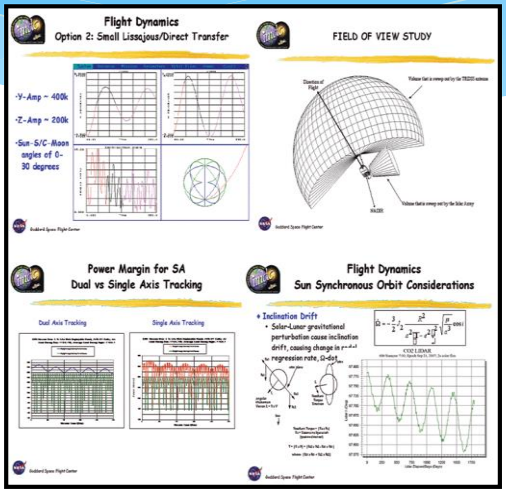
- Instrument Cost 158
- Reliability 371
- Materials 541
- Structural 542
- Mechanical Systems 543
- Electro-mechanical 544
- Thermal 545
- Contamination 546
- Mechanical Designer 547
- Team Lead/ Deputy Team Lead 550
- Optics 551
- Cryogenics 552

- Detectors 553
- Electro-optics/Lasers 554
- Microwave Systems 555/567
- Radiation Environment 561
- Instrument Electronics 564
- Integration and Test 568
- Flight Software 582
- Fine Guidance 591/595
- Instrument Systems Engineer 592
- Planetary Protection 592
- Orbital Debris 592

Tools

Software

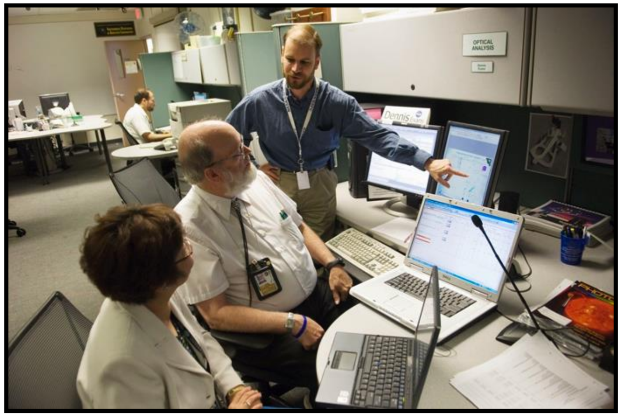
- Mix of Commercial-Off-The-Shelf (COTS) and homegrown engineering software such as:
    - STK/Free Flyer
    - NX
    - FEMAP
    - MathCAD
    - Mathematica
    - PATRAN/NASTRAN
    - MATLAB/Simulink
    - Working Model 2D
    - CREO
    - SolidWorks
    - SINDA
    - Code V
    - ZEMAX
    - TSS/Thermal Desktop



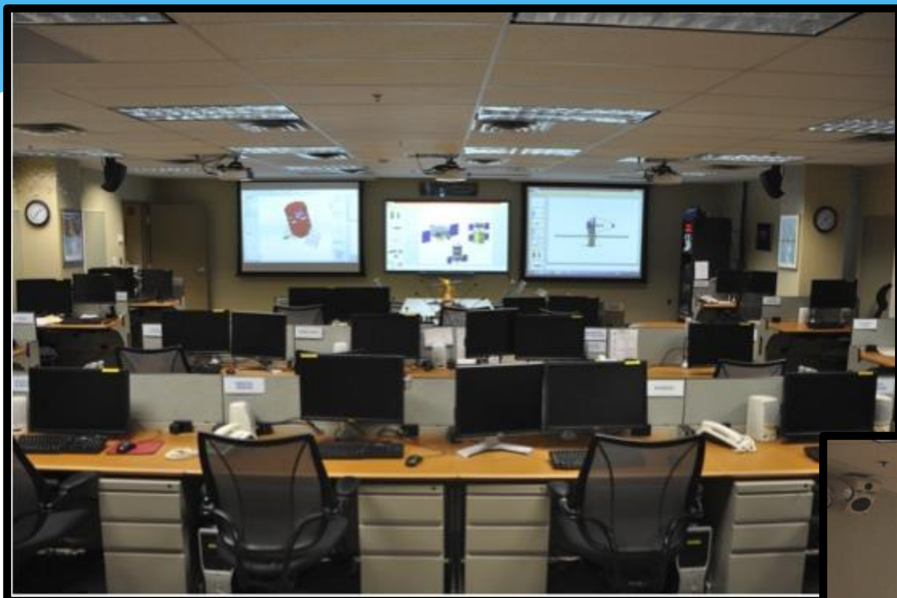
- Systems engineering integration software
    - Automatic gathering, integration and display of engineering parameters

Hardware

- State-of-the-art computing platforms
- Independent, integrated IT solutions
    - Servers, networks, web-drives
- Communication and audio-visual
    - WebEx, station telecom, projection, product preparation



Facilities



State-of-the-art engineering workstations, software and information technology to ensure engineering excellence.

Mission Design Lab (MDL)

Comfortable, well-equipped workspaces to facilitate dynamic interaction within team

Instrument Design Lab (IDL)

Process

Concurrent, collaborative, systems engineering:

- All required engineering disciplines work simultaneously for study duration
- Customer team integrated into design process
- Systems Engineers infuse end-to-end system and mission life-cycle perspectives
- Lab Lead manages customer needs, schedule, product consistency and quality

Rapid, responsive, evolving concept design development:

- Evaluate and iterate concept design in real-time
- Discipline engineers use consistent conventions to represent the design
- Systems engineers use collaborative tools to rack up engineering resources
- Routine study milestones are used to evaluate progress and make key decisions

Proven approach:

- Within a reasonable scope of work, the outcome of the study is credible and costable

IDL – Services and Capabilities

Services:

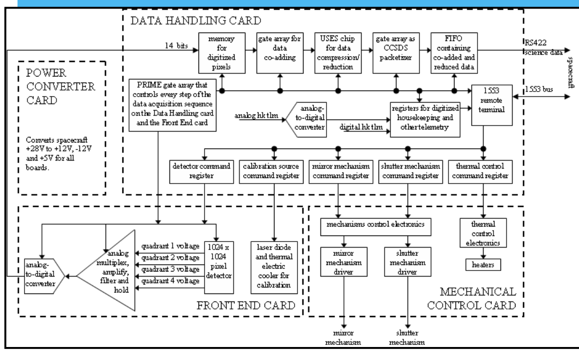
- End-to-end instrument concept development
- Existing instrument/concept architecture evaluations
- Trade studies and engineering evaluations
- Technology, risk, and independent assessments
- Requirement refinement and science traceability
- Mass, power, data resource allocation
- Vendor RFQ evaluation
- Cost estimation

Capabilities:

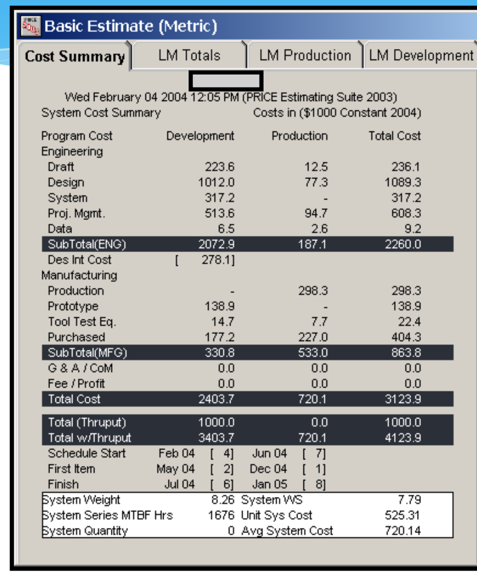
- Conceptualize instruments that make measurements at wavelengths across the entire electromagnetic spectrum, including x-ray, gamma ray, ultra-violet, visible, infrared, and microwave instruments
- Address instrument families ranging from telescopes, cameras, lidars, spectrometers, polarimeters, coronographs, radiometers, mass spectrometers, etc.
- Model various flight environments, including LEO, GEO, libration, retrograde, away, lunar, deep space, and planetary orbiters, landers, and probes
- Realize instruments for different flight platforms, including space station, balloon, sounding rockets, and UAV instrument design environments
- Consider non-distributed and/or distributed instrument systems as well as robotic servicing, planetary rovers, and sample return

IDL Product Examples

Electrical Subsystem Architecture



Cost Modeling

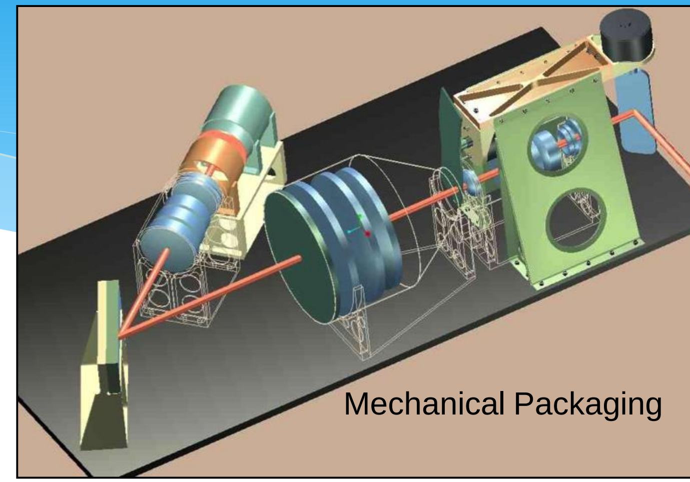


Wed February 04 2004 12:05 PM (PRICE Estimating Suite 2003)

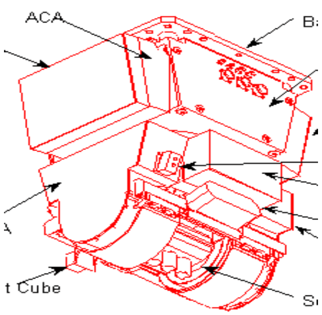
System Cost Summary — Costs in ($1000 Constant 2004)

Program Cost	Development	Production	Total Cost
Engineering			
Draft	223.6	12.5	236.1
Design	1012.0	77.3	1089.3
System	317.2	-	317.2
Proj. Mgmt.	513.6	94.7	608.3
Data	6.5	2.6	9.2
SubTotal(ENG)	2072.9	187.1	2260.0
Des Int Cost	[278.1]		
Manufacturing			
Production	-	298.3	298.3
Prototype	138.9	-	138.9
Tool Test Eq.	14.7	7.7	22.4
Purchased	177.2	227.0	404.3
SubTotal(MFG)	330.8	533.0	863.8
G & A / CoM	0.0	0.0	0.0
Fee / Profit	0.0	0.0	0.0
Total Cost	2403.7	720.1	3123.9
Total (Thruput)	1000.0	0.0	1000.0
Total w/Thruput	3403.7	720.1	4123.9
Schedule Start	Feb 04 [4]	Jun 04 [7]	
First Item	May 04 [2]	Dec 04 [1]	
Finish	Jul 04 [6]	Jan 05 [8]	

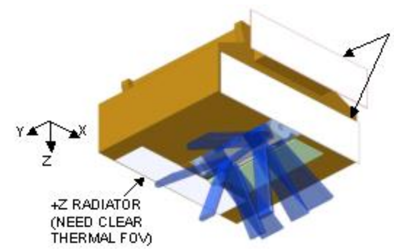
System Weight	8.26	System WS	7.79
System Series MTBF Hrs	1676	Unit Sys Cost	525.31
System Quantity	0	Avg System Cost	720.14



Mechanical Packaging

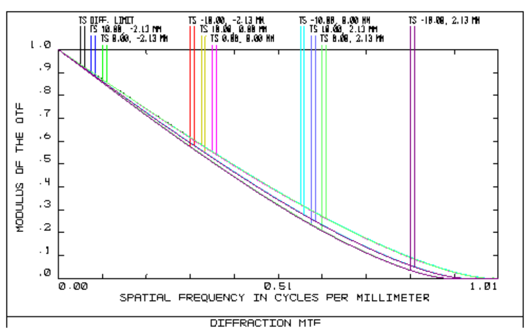


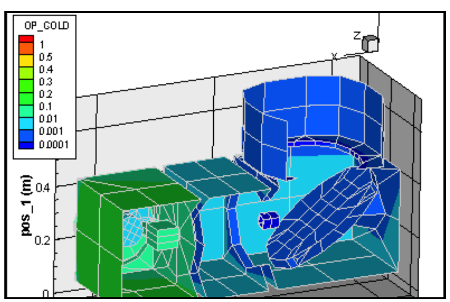
Mechanism Design



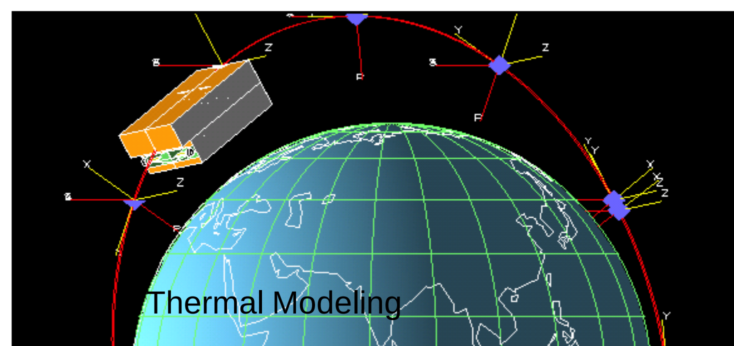
Radiator Placement

Optical Performance Assessment





Contamination Assessment



Thermal Modeling

MDL – Services and Capabilities

Services:

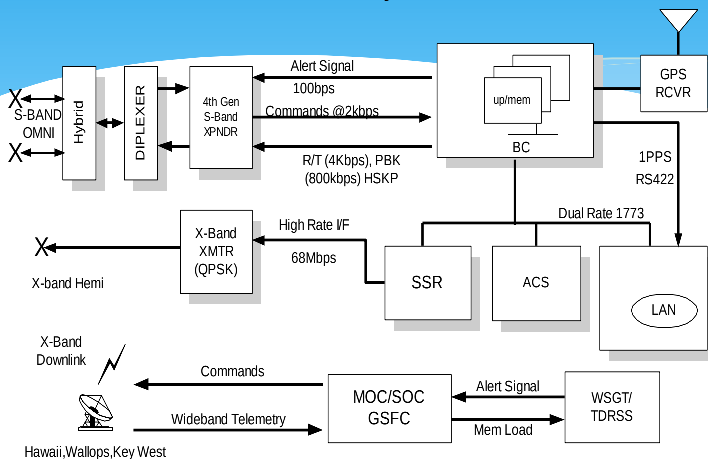
- End-to-end mission concept development
- Engineering evaluations
- Trade studies
- Technology, risk, and independent assessments
- Requirement refinement and science traceability
- Mass, power, data resource allocation
- Master Equipment Lists for cost modeling

Capabilities:

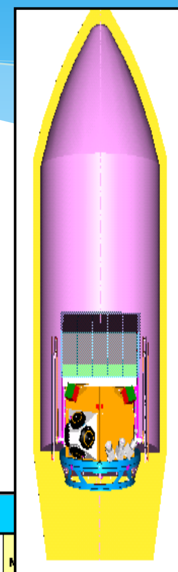
- Standard and low thrust trajectory design to LEO, GEO, libration, lunar, and deep space locations
- Observatory design of single spacecraft, constellations, formation flying, and distributed systems
- Ground system concept development, including services and products
- Launch vehicle accommodations
- End-of-Mission considerations including controlled and uncontrolled de-orbit, reconnaissance and landing, sample return, etc.

MDL Product Examples

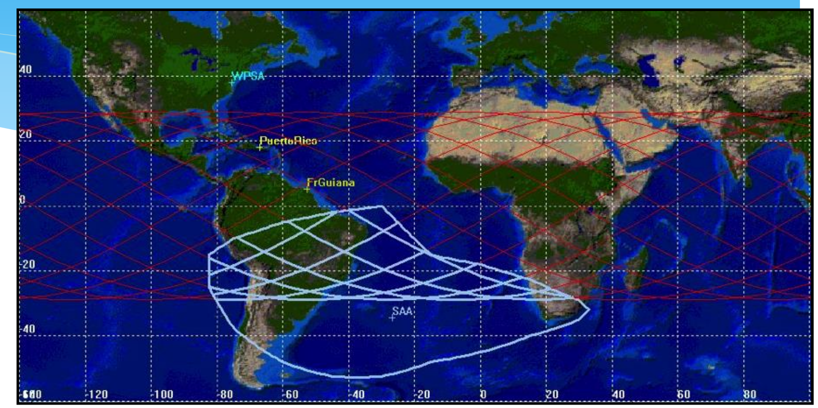
Spacecraft Systems Block Diagrams and Performance Analyses



Launch Systems Accommodations and Performance Analysis



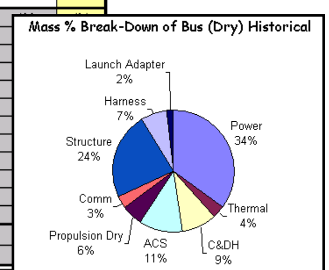
Systems Engineering, I&T, Operations, Risk Assessment, Mission Costing

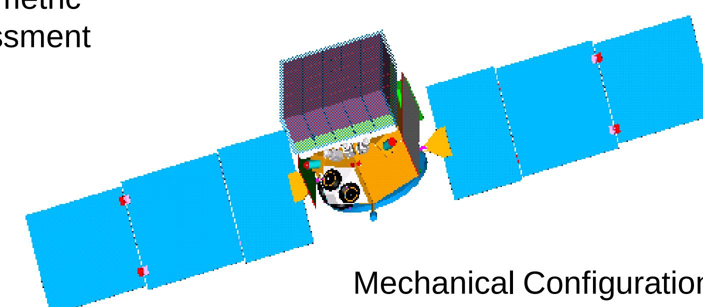


Orbit, Communications, Ground Systems, Environmental Analyses

BUS AND STRUCTURE	DELTA (745 kg liftoff) As presented on March 7				Hist. Avg.	TAURUS (310 kg liftoff)				ATHENA (425 kg liftoff)			
Subsystem	Act Mass [kg]	Cont Mass [kg]	Act Mass Dry %	Act Mass Wet %	Dry %	Prel Mass (Calc w/ Wet Mar 7 %'s) [kg]	Final Assgned Act Mass [kg]	Final Cont Mass (w/ Mar 7 Cont %'s) [kg]	Final Mass % (Calc fm Assgned Dry) %	Prel Mass (Calc w/ Wet Mar 7 %'s) [kg]	Final Assgned Act Mass [kg]	Final Cont Mass (w/ Mar 7 Cont %'s) [kg]	(Calc fm Assgned Dry) %
Bus Structure	20.0	25.0	5.9	3.1	24	8.2	40.0	50.0	24.9	10.5	40.0		
RF Masts, Dishes, Gimbals	5.0	6.3	1.5	0.8		2.0	3.3	4.2	2.1	2.6	4.0		
ACS	43.2	49.7	12.6	6.8	11	17.6	15.0	17.3	9.4	22.7	25.0		
C&DH	18.8	22.6	5.5	2.9	9	7.7	7.5	9.0	4.7	9.9	9.5		
Power System	25.8	29.7	7.6	4.0	34	10.5	9.2	10.6	5.7	13.6	15.0		
Solar Arrays, Drives, Electronics	119.8	143.8	35.1	18.8		48.9	40.0	48.0	24.9	63.0	51.9		
Bus Harness	3.0	3.8	0.9	0.5	7	1.2	6.7	8.3	4.2	1.6	6.9		
Thermal Hardware	21.0	26.3	6.1	3.3	4	8.6	7.5	9.4	4.7	11.0	10.4		
RF Communications	47.0	54.1	13.8	7.4	3	19.2	16.7	19.2	10.4	24.7	24.0		
Separation System, spacecraft side	2.0	2.2	0.6	0.3	2	0.8	2.0	2.2	1.2	1.1	2.0		
Propulsion	36.1	41.5	10.6	5.7	6	14.7	12.5	14.4	7.8	19.0	17.3		
Propellant	296.4	296.4	86.7	46.5		121.0	121.0	121.0	75.4	155.8	155.8		
DRY MASS (BUS ONLY)	341.7	404.7				139.5	160.4	192.5		179.6	205.9		
WET MASS (BUS ONLY)	638.1	701.1				260.4	281.4	313.5		335.4	361.7		
MISSION TOTALS:	Actual	Contingent					Assigned	Contingent			Assigned	Contingent	
PAYLOAD TOTAL	18.0	22.5					18.0	22.5			18.0	22.5	
BUS SUBSYSTEMS DRY TOTAL	341.7	404.7					160.4	192.5			205.9	237.2	
BUS + PAYLOAD DRY TOTAL	359.7	427.2					178.4	215.0			223.9	259.7	
PROPELLANT	296.4	296.4					121.0	121.0			155.8	290.9	
LAUNCH MASS (WET BUS + PAYLOAD)	656.1	723.6					299.4	336.0			379.7	550.6	
LV capability to nom. orbit	745.0	745.0					335.0	335.0			425.0	425.0	
Wet Bus + Payload Margin [kg]	88.9	21.4					35.6	-1.0			45.3	-125.6	
Wet Bus + Payload Margin [%]	11.9	2.9					10.6	-0.3			10.6	-29.6	
Dry Bus + Payload Margin [%]	24.7	5.0					19.9	-0.5			20.2	-48.4	

Parametric Assessment





Mechanical Configurations and Thermal Analyses

Probe Class Study Schedule

Probe Class Teams	FY17			FY18						
	July	August	September	October	November	December	January	February	March	April
POEMMA	IDL (Wk of 31st)			MDL (Wk of 30th)						
CETUS				IDL (Wk of 30th)			MDL (Wk of 22nd)			
TAP					MDL (Wk of 13th)				IDL (Wk of 19th)	
STROBE-X					IDL (Wk of 27th)					MDL (Wk of 9th)
AXIS							IDL (Wk of 22nd)	MDL (Wk of 26th)		

Next Steps …

(The IDC Manager and Lab Leads will guide you through the process)

Planning and preparation

- IDL & MDL pre-work forms will be provided to GSFC assigned teams
- Schedule planning meetings 2-3 months prior to each study to meet with lab leads and systems engineers. Customers should provide a relatively detailed description of the mission or instrument with supporting charts, models, and related materials.
- Pre-work meeting is held 2-4 days before study and includes the entire cadre of discipline engineers assigned to the study. Customer will review the completed pre-work forms at this time.

Study execution

- Our studies are typically limited to 1 week in duration, with customer participation expected the first 3 days of the study (tag-up meetings twice daily at 9:30am and 1:30pm).
- The IDL/MDL team works internally on the 4th day.
- On the 5th and final day, study results will be briefed to the customer team.
- The IDL/MDL team also works internally 1 day following the study to close-out any actions identified during the final briefing.

Next Steps …

(The IDC Manager and Lab Leads will guide you through the process)

Cost Presentation

- All study products that are executed following the study week are presented at a later date.
- Typically the cost estimate and structural analysis results are presented 7-10 business days after the study.

Final Study products

- Provided following the cost and structural analysis presentation, and will include all updated presentation material, as well as the detailed study results/models produced by each of the discipline engineers.
- Please note: Your study product should be considered a first in a series of iterations that your team will take to mature your instrument and mission concepts and to resolve technical issues the IDC teams have identified outside the scope of the study.

- **Instrument Design Lab (IDL)** - offering conceptual design and analysis of instrument systems (building 23, room C340)

- **Mission Design Lab (MDL)** - offering conceptual end-to-end mission design and analysis (building 23, room C318)

- **Architecture Design Lab (ADL)** - offering rapid mission level trade space exploration and architecture options assessment (building 23, room C310)

2020 Astrophysical Decadal Survey Probe Studies

Design Guidelines, Rules of Thumb,

and

Final Deliverable: Contents, Page Limits

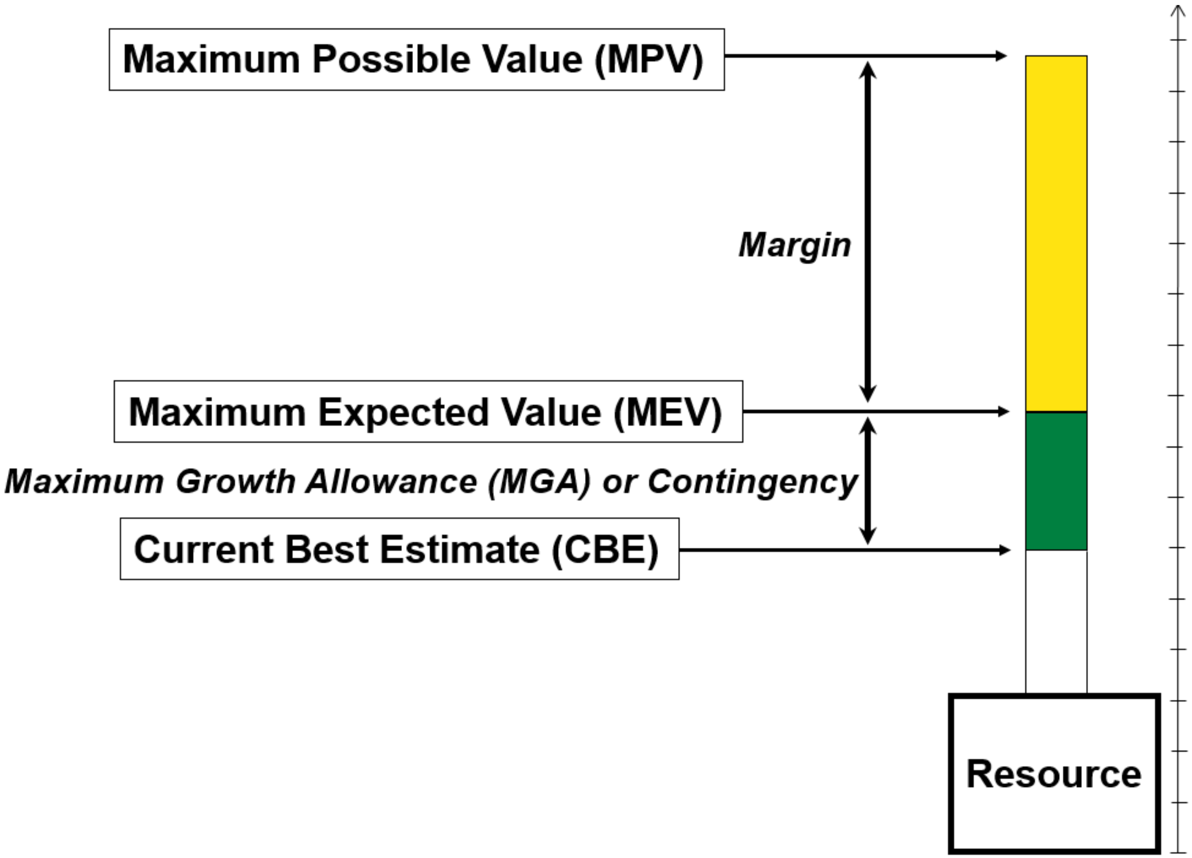
Keith Warfield, ExEP Chief Engineer
Gabe Karpati, PCOS / COR Chief Engineer

Design Guidelines - Overview

- **Aerospace Corp. has reviewed the Design Guidelines used in the Concurrent Design Labs the Probe Studies will use (IDC and Team-X), in order to assess if their processes are robust enough for an independent cost estimate.**
  - This review was actually conducted in preparation for the CATE effort for the Large Studies, however its findings are equally applicable to the Probe studies.
- **The guidelines reviewed were:**
  - **"IDL/MDL Design Guidelines" - for the Probes Studies assigned to GSFC's IDC**
  - **"JPL Design Principles" - for the Probe Studies assigned to JPL's Team-X**
- **Overall, the Aerospace review found that the IDC and Team-X guidelines were in reasonable agreement with its own guidelines, but the following additional mass and power guidelines should also be considered:**
  - **ANSI/AIAA-G-020-1992 entitled "Estimating and Budgeting Weight and Power Contingencies for Spacecraft Systems" provides guidance at the system level for new designs in conceptual design stage**
  - **ANSI/AIAA-S-120A-2015 entitled "Mass Properties Control for Space Systems" provides additional guidance at the subsystem level for different levels of design maturity**

Contingency and Margin Definitions

- **Contingency: a possible occurrence or result**
- **Margin: an amount beyond the necessary**



ANSI/AIAA-G-020-1992 Mass Contingency Guidelines

Table 1: Guide for Estimating and Budgeting Weight and Power Contingencies for Spacecraft Systems (AIAA-G-020-1992)

	Minimum Standard Weight Contingencies (Percents)														
Description/ Categories	**Proposal Stage**			**Design Development Stage**											
	Bid Class*			**CoDR** Class			**PDR** Class			**CDR** Class			**PRR** Class		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Category AW 0 to 50 kg. 0 to 110 lbs.	50	30	4	35	25	3	25	20	2	15	12	1	0	0	0
Category BW 50 to 500 kg. 110 to 1,102 lbs.	35	25	4	30	20	3	20	15	2	10	10	1	0	0	0
Category CW 500 to 2,500 kg. 1,102 to 5,511 lbs.	30	20	2	25	15	1	20	10	0.8	10	5	0.5	0	0	0
Category DW 2,500 kg. & up	28	18	1	22	12	0.8	15	10	0.6	10	5	0.5	0	0	0

*Note: Class 1 = New Design, Class 2 = Generational, Class 3 = Production

ANSI/AIAA-G-020-1992 Power Contingency Guidelines

Table 2: Guide for Estimating and Budgeting Weight and Power Contingencies for Spacecraft Systems (AIAA-G-020-1992)

	Minimum Standard ***Power*** *Contingencies (Percents)*														
Description/ Categories	**Proposal Stage**			**Design Development Stage**											
	Bid Class *			**CoDR** Class			**PDR** Class			**CDR** Class			**PRR** Class		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Category AP (0 to 500 watts)	90	40	13	75	25	12	45	20	9	20	15	7	5	5	5
Category BP (500 to 1,500 watts)	80	35	13	65	22	12	40	15	9	15	10	7	5	5	5
Category CP (1,500 to 5,000 watts)	70	30	13	60	20	12	30	15	9	15	10	7	5	5	5
Category DP (5,000 watts & up)	40	25	13	35	20	11	20	15	9	10	7	7	5	5	5

*Note: Class 1 = New Design, Class 2 = Generational, Class 3 = Production

ANSI/AIAA-S-120A-2015 Mass Contingency Guidelines

Table 1 — Mass Growth Allowance by Design Maturity

Maturity Code		Design Maturity (Basis for Mass Determination)	Percentage Mass Growth Allowance: Electrical/Electronic Components 0-5 kg	5-15 kg	>15 kg	Primary Structure	Thermal Control	Propulsion, Fluid Systems Hardware	Batteries	Wire Harnesses	Solar Array	ECLSS, Crew Systems	Secondary Structure	Mechanisms	Instrumentation
E	1	**Estimated**	20-35	15-25	10-20	18-25	30-50	15-25	20-25	50-100	20-35	20-30	20-35	18-25	25-75
	2	**Layout**	15-30	10-20	5-15	10-20	15-30	10-20	10-20	15-45	10-20	10-20	10-25	10-20	20-30
C	3	**Preliminary Design**	8-20	3-15	3-12	4-15	8-15	5-15	5-15	10-25	5-15	5-15	8-15	5-15	10-25
	4	**Released Design**	5-10	2-10	2-10	2-6	3-8	2-7	3-7	3-10	3-5	3-8	3-8	3-4	3-5
A	5	**Existing Hardware**	1-5	1-3	1-3	1-3	1-3	1-3	1-3	1-5	1-3	1-4	1-5	1-3	1-3
	6	**Actual Mass**	Measured mass of specific flight hardware; no MGA; use appropriate measurement uncertainty.												
S	7	**CFE or Specification Value**	Typically, an NTE value is provided, and no MGA is applied.												

Expanded Definitions of Maturity Categories

E1	**Estimated**	a. An approximation based on rough sketches, parametric analysis, or incomplete requirements b. A guess based on experience c. A value with unknown basis or pedigree
E2	**Layout**	a. A calculation or approximation based on conceptual designs (equivalent to layout drawings or models) prior to initial sizing b. Major modifications to existing hardware
C3	**Preliminary Design**	a. Calculations based on new design after initial sizing but prior to final structural, thermal or manufacturing analysis b. Minor modification of existing hardware
C4	**Released Design**	a. Calculations based on a design after final signoff and release for procurement or production b. Very minor modification of existing hardware
A5	**Existing Hardware**	a. Measured mass from another program, assuming that hardware will satisfy the requirements of the current program with no changes b. Values substituted based on empirical production variation of same or similar hardware or measured mass of qualification hardware c. Catalog values

NOTE: The MGA percentage ranges in the above table are applied to the basic mass to arrive at the predicted mass.

* Note: "Estimated" design maturity is appropriate for pre-phase A conceptual designs given that the requirements are still in flux and the concept itself will also change

Design Guidelines - Summary

- **Overall it is best to provide higher Contingencies in early conceptual design, as they provide more robust and flexible development envelopes to address future unknown development issues**
- **Aerospace suggests using ANSI/AIAA guidelines for mass and power Contingencies in early conceptual design**
- **System level Margin is always accounted for above and beyond the sum of Contingencies**

- **MASS:**
  - **The mass Contingencies from ANSI/AIAA-G-020-1992 are 30% to 35%**
  - **The sum of mass Contingencies plus the system level mass Margin usually amounts to ~ 42% to 50% of the total Launch Vehicle throw mass capability**

- **POWER:**
  - **Total system level Contingency from ANSI/AIAA-G-020-1992: 40% to 80%**
  - **Subsystem guidance provided from ANSI/AIAA-S-120A-2015**

- **Projects should consider establishing higher mass and power Contingencies to science instruments given that those are typically more developmental and experience higher mass and power growth than spacecraft busses: 50% mass and 75% power Contingencies suggested**

- **Projects don't have to use identical guidelines, but should provide a rationale for basis of Contingency stated.**

Costing Rules of Thumb

- **Rule #1: The spacecraft and payload costs are about half of the total cost**

Total Sample Budget	**$1,000M**
- L/V	120M to 260M
- Reserves	200M to 170M
- Operations (5yrs@$15M/yr)	75M
- Mgmt, Sys Engrg, Mission Assurance	40M
- Ground System Dev. And Ops Team	40M
- Pre Launch Science, EPO, and Misc.	20M
Sum Non-Spacecraft/Payload:	*495M to 605M*
Total Remaining for Spacecraft, Payload and ATLO	**$500M to $400M**

- **The Total of Launch Vehicle and Reserves can be ~ 1/3 to 1/2 of the $1B Budget**
  - **Non-hardware costs have limited potential for savings**
  - **Launch mass becomes a significant cost driver**

Costing Rules of Thumb (cont'd)

- **OTS S/C bus able to handle a 500kg payload costs $80-$180M**
  - Costs based on a 2011 Team X survey of OTS S/C vendors
  - All will likely need uncosted upgrades to meet pointing and other requirements
  - Cost includes ATLO
  - Generally, lower cost equals lower capability
  - Data point: the Kepler spacecraft cost was $150M in $FY15 (NASA CADRE data)
- **Instruments typically cost $800-1000k/kg**
  - Based on NASA Instrument Cost Model (NICM) actual instrument costs
  - Assumes Class B Earth orbiting mission
  - Does not include telescope
  - Does not include technology development
- **An on-axis 1.0-1.5m telescope costs $50-110M**
  - Based on 2013 cost model inflated into $FY15
  - Assumes 1st unit and visible spectrum
  - Off axis costs a bit more and is heavier
- **Second unit cost is about 50% of the first unit cost**
  - Based on NICM instrument re-flight data and 1996 Aerospace Small Satellite Subsystem Cost Model ver. 2.0 data
  - Varies between 20-80% but averages around 50%
  - The second unit should be close in time to the first unit to be credibly build-to-print

Misc. Rules of Thumb

- **Mass or Power combined contingency and margins should be 40-50% of Current Best Estimate (CBE)**
- **Instrument mass/power ratio is typically 1 kg/W**
- **Electronics in card boxes typically have mass/volume = density of water i.e. 1 kg/liter (1000 kg/m^3)**
- **Acceptable spacecraft bus densities are 250 – 400 kg/m^3. At higher densities I&T becomes complicated and expensive.**
- **More mass can be delivered to Earth-Sun L2 or Earth Trailing/Leading orbits than to Geostationary due to the delta-v cost of raising periapsis**
- **Radiation at Geostationary is much worse than Earth-Sun L2, Heliocentric, or LEO**
- **Geostationary has eclipses. Earth-Sun L2 not necessarily, not even partial, ever**

Final Deliverable – Definition Of Content

- **The Final Deliverable should be science heavy**
  - The Decadal Panel makes its recommendations based on science, or more specifically based on the science for the costs stated.
- **The Final Deliverable should cover areas similar to a typical AO response**
  - Although not with the same exact emphasis and proportions. Your document should be relatively heavier on science.

- **Suggested Contents of the Final Deliverable** (this is only a recommendation for a typical case, and is by no means limiting or binding)**:**
  - Overview, Participants
  - Science Case
  - Observations, Measurements, Design Reference Mission (w/ Science Yield Estimate)
  - Instrumentation, Payload, Optics, Detectors, etc.
  - Mission Design, Observatory, Spacecraft, Launch Vehicle, Ground Stations, etc.
  - Concept of Operations
  - Technology, Technology Roadmaps
  - Schedule
  - Cost, PI Team's Estimate with Justification

Final Deliverable – Page Limits

- **Strongly suggest keeping the page count of the Final Deliverable main document between 20 and 40 pages**
  - This page count assumes conventional “proposal style” formatting comparable to the THEIA White Paper shown as a sample on the next slide
- **At least half of the Final Deliverable main document should cover:**
  - the science case
  - observations, and
  - science yields
- **Appendices are allowed but not required, and are unlimited in page count and format**
  - Add Appendices to the Final Deliverable at your own risk! Don’t assume the Decadal Panel or the ICE will even look at them!
- **Your Final Deliverable paper will be released to the public. No ITAR sensitive material!**

THEIA
Telescope for Habitable Exoplanets and Interstellar/Intergalactic Astronomy

White Paper Submitted to NRC ASTRO-2010 Survey

Prof. N. Jeremy Kasdin
Mechanical and Aerospace Engineering
Princeton University
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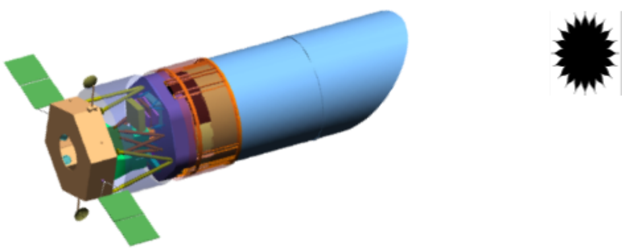

Co-Investigators

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Industry Partners: Lockheed Martin Missiles and Space, ITT Space Systems, LLC, Ball Aerospace
NASA Partners: Jet Propulsion Laboratory/Caltech, Goddard Space Flight Center, Ames Research Center, Marshall Space Flight Center
University Partners: Arizona State University, Caltech, Case Western Reserve University, University of Colorado, John Hopkins University, University of Massachusetts, University of Michigan, MIT, Penn State, Princeton University, Space Telescope Science Institute, University of California-Santa Barbara, University of California-Berkeley, University of Virginia, University of Wisconsin, Yale University

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Sample Final Deliverable:
- the THEIA White Paper

https://www.princeton.edu/~hcil/papers/theiaWhitePaper.pdf

- This was an actual submission to the 2010 Astrophysical Decadal Survey -

Probes Studies Management and Process

Technology For Probes

Rita Sambruna, Probe Studies Program Scientist
Shahid Habib, Probe Studies Program Executive
Astrophysics Division, NASA Headquarters
May 19, 2017

Technology for Probes mission concepts

- The funding for the selected Probe Study does **<u>not</u>** include funds for technology maturation. NASA will **<u>not</u>** provide separate funds for technology maturation to the study teams. Technology maturation is being accomplished through the normal APRA and SAT processes. Decadal prioritization will be needed first to change current technology maturation funding priorities.
- The final Study report should provide a list of technologies needed to accomplish the mission (a “Technology gap” list), and a roadmap for its maturation should the Probe mission concept be prioritized by the Decadal
- NASA will include planning for the maturation of technologies needed for all Decadal Survey prioritized activities (including large and medium missions) in its planning for the 2020s that will follow the Decadal Survey.

Astro Probe Mission
Independent Cost Assessment

May 19, 2017

Cindy Daniels
Director

Science Office for Mission Assessments
(SOMA)

ICA for Astrophysics Probes Missions

- The Science Office for Mission Assessments (SOMA) has been asked to perform an Independent Cost Assessment (ICA) on 9 Astrophysics Probe Missions studies selected from the ROSES competition.
- The SOMA office at LaRC is firewalled off from Langley to provided independent evaluations of Science Mission Directorate missions and instruments.
- SOMA has experience estimating the cost of Astrophysics missions through the Astrophysics Explorer Program Announcement of Opportunity process.
- SOMA also has experience estimating costs as a result of a ROSES competition selection
  - SOFIA 3rd Generation Instrument

ICA for Astrophysics Probes Missions

- SOMA is reviewing example reports from the GSFC IDL and JPL Team X for content needed to do an ICA.
- SOMA will provide a document to the PIs, the IDL lead and the Team X lead describing the information needed for SOMA to produce and ICA.
- HQ will transmit the Team-X and IDL products to SOMA
  - Will we receive 9 reports all at once or incrementally?
- After SOMA receives the final report on each mission from the GSFC and IDL, SOMA will review the material and generate an ICA.
- SOMA would like to have a telecon to ask questions on each report before we finalize the ICA.
- SOMA’s products will be delivered directly to HQ.

Summary of the Information Required for ICA
DRAFT

DRAFT Technical Inputs

- **Mission concept description.** A stand-alone, concise description of the mission. Length 10-20 pages, modeled on white papers submitted to 2010 astrophysics decadal survey. Must include mission overview, science objectives, technical approach (spacecraft and each instrument), key development challenges, management (organization, schedule) and cost estimate.
- **Instrument Description.** Each mission will require additional effort to develop an instrument design that is sufficiently detailed to support technical and cost estimates. These should include block diagrams of the system, each instrument and each subsystem. For optical instruments, include optical layout diagram showing key components (imaging mirrors, dichroics, etc).
- **Measurement requirements and derived hardware requirements.** Summary of key requirements (with compliance). Depending on the mission, these could be instrument SNR, thermal (cryo), pointing and stability, etc.

DRAFT Heritage, TRL Inputs

- Need to identify design sources and how appropriate they are for the application being considered. Items that should be addressed include previous applications, environments, obsolescence and changes to heritage.
- Top level Heritage and TRL assessment for instruments and flight systems. Information should ideally go down to lower subsystem levels or components.
- Identification of any components which are judged to be below TRL 6. TRL maturation plan and estimate of the scope of technology development required.

DRAFT Cost Inputs

- Basis of Estimate (BOE) information (to the lowest WBS) level possible.
  - If parametric is the primary estimating approach, as much detail as possible on the model inputs and outputs.
  - If extrapolation from analogous systems is used, as much detail as possible regarding the analogous system cost and how it was adjusted to form the basis for the proposed new system.
  - If bottoms up is used, as much detail as possible regarding the cost build up (specifically material vs labor assumptions).
- Description of major contributions (if any are expected)
- Top level Identification of key cost risks
- Cost summary table (in Constant Year TBD$) by WBS element and phase
- List of major procurements with cost estimates
- Provide breakout of electronics down to module level.
- Need WBS dictionary or enough detail within BOE to fully understand activities captured within.

DRAFT Schedule input

- Summary level schedule with as much detail as is available (Instruments, flight system, GSE, flat-sats, I&T, launch site)
- Integration and test flow or description
- Clearly identified critical path (if possible) and funded schedule reserves (or assumptions)
- Heritage and TRL description to validate schedule durations

DRAFT Detailed MEL inputs

- A MEL should be provided with the report. At a minimum, the breakdown needs to be at the subsystem level but ideally at the component level.
- List major procurements and vendors.
- Needs to apply to all proposed instruments and spacecraft.
- Each line item of MEL should include CBE mass, CBE power, mass contingency, power contingency, mass margin, power margin, number of engineering units and number of flight units.
- Identify vendors in MEL

DRAFT Margins Inputs

- Need clear presentation of requirements and technical margins. Include budgets and margins for instrument performance, mass, power, propellant, pointing (control, stability, jitter), data, data volume, communication links Instrument sensitivity, thermal control, calibration accuracy.
- Margins recommended:
  - Mass margin ≥ 30%
  - Power margin ≥ 30% at EOL under worst-case mode
- Maturity-based mass and power contingency
- Propellant budget based on 3 sigma assumptions
- Link margins ≥ 3 dB under worst case assumptions
- Budgets must include current best estimate, contingency values, and margins as defined in the standard AO

DRAFT Other general inputs

- The expected mission classification should be established and communicated to the study participants. If SMD is looking for a “Flagship” category mission then Class A should be assumed. The risk categorization impacts cost by impacting assumptions on parts quality, reliability, redundancy, etc.
- A preliminary assessment of the mission radiation environment should be included.
- Some high-level description of operations should be provided such as targeted vs. survey, command frequency, type of data processing (e.g. does it require a new pipeline?) that would allow sufficient information for a sanity check on the operations costs.
- List of major partners
- Special GSE or test equipment needed

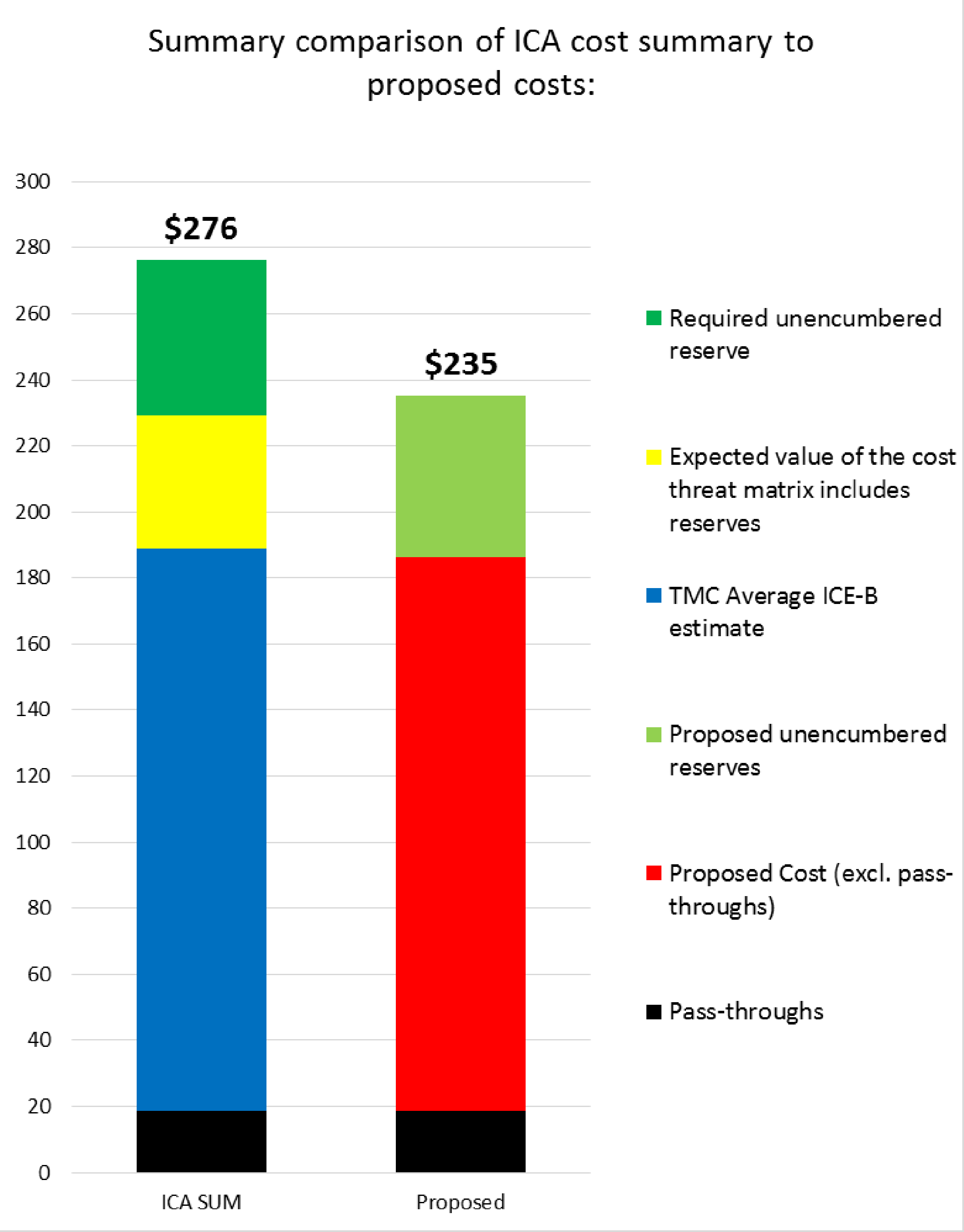
ICA Product
DRAFT

DRAFT Product Summary

- Final Independent Cost Assessment report will be similar to SOMA Cost Evaluation Summary (CES) report to include:
  - Summary Cost Tables comparing ICE to proposed costs. ICE will be based on proposed cost assumptions provided in Team X or IDL design center documents.
  - Cost Threat Matrix delineating added costs above ICE baseline results
  - Will include recommended added reserves
  - Combined results will be illustrated in bar chart format similar to SOMA product 4 chart
  - Costs provided at various confidence levels to give sense of cost risk

DRAFT Summary cost chart

- Summary Cost Charts consolidating results
  - Baseline ICE
  - Pass-throughs
  - Recommended reserves
  - Added value of cost threats above ICE baseline
  - Costs cover Phases A-D



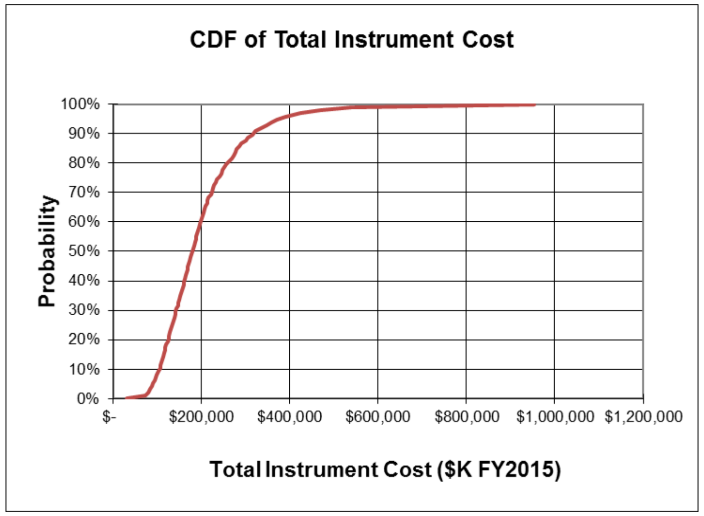
DRAFT Report Comments

- Report to include comments on other key issues that could impact cost
  - Technical Maturation
  - Schedule challenges
  - Heritage Assumptions
  - Technical performance margins
  - Requirements

DRAFT ICE Models

- Cost modeling with various parametric cost models
  - NASA cost models
  - Commercial Component Level Models (SEER H, IC, EOS and SEM)
- Models results obtained at various confidence levels to provide a sense of cost risk
- Model inputs will use distribution shown below in table to the right
- ICE results are one input in summary bar
- Results provided at multiple levels of confidence to provide sense of risk reflected in model results.
  - 50% reflect common baseline costs
  - 70% for higher confidence level

Model Input Distribution		
Least	**Likely**	**Most**
MEV (CBE + contingency)	MPV (MEV + Margin)	MPV + 30%



Model Estimate			
Probability	30%	50%	70%
Total Instrument	$142,804	$178,995	$223,173
Management	$10,069	$12,741	$16,032
Sys. Engrg.	$10,664	$12,988	$15,745
Prod. Assurance	$7,392	$9,165	$11,305
I & T	$15,628	$19,665	$24,610
Total Sensor	$99,051	$124,436	$155,481
Optics/Antenna	$16,786	$20,037	$24,000
Electronics	$49,673	$64,319	$83,228
Mech/Structures	$24,438	$30,457	$36,701
Thermal/Fluid	$0	$0	$0
Detectors	$2,877	$3,685	$4,970
Software	$5,278	$5,937	$6,581

2020 Astrophysical Decadal Survey Probe Studies Kickoff Meeting

Q & A

Question on Technology Maturation Costing

QUESTION:

If any of the Probes flies, it will be launched toward the end of the next decade at the earliest. Its Phase A is several years away, say, 5 or 6 years. Technologies mature over time, some of them rapidly. Some technologies that are currently TRL 3,4 will have TRL 5,6 by the time Phase A begins, perhaps higher.

How do the costing teams and the independent estimator plan to factor routine maturation of technologies? How should the teams handle the issue?

ANSWER:

Technology doesn't mature by itself over time. There is no "routine maturation of technologies" in aerospace. Either somebody is doing funded technology work - in which case you should point at that - or it's not happening. Moore's Law only works for the consumer market.

Also, see the HQ presentation's slide on Technology:

The funding for the selected Probe Study does <u>not</u> include funds for technology maturation. NASA will <u>not</u> provide separate funds for technology maturation to the study teams. Technology maturation is being accomplished through the normal APRA and SAT processes. Decadal prioritization will be needed first to change current technology maturation funding priorities.

The final Study report should provide a list of technologies needed to accomplish the mission (a "Technology gap" list), and a roadmap for its maturation should the Probe mission concept be prioritized by the Decadal

NASA will include planning for the maturation of technologies needed for all Decadal Survey prioritized activities (including large and medium missions) in its planning for the 2020s that will follow the Decadal Survey.

Question on “Dumb” Mass’s Effect on Cost Estimate

QUESTION:

We have to design our instruments with a minimum number of reflections to avoid losses in optical efficiency. This means no fold mirrors that would make for compact instrument. Instead, our optical design is quite long and the structure more massive. Given the volume and lift capabilities of the Falcon 9, added mass is not a problem and would probably make the payload cheaper.

The question is: How important is total mass to the estimated overall cost of a probe mission in the era of the Falcon 9? Estimated costs based on history don't seem to be applicable without major modification.

ANSWER:

It is up to each Probe Team, to make the case in their final report that the mission concept is not on a regular mass cost curve. In other words, make it clear in your report that the added mass is not penalizing you in terms of added cost.

Also, don’t give full credit to the “1kg = $1M” urban myth. Instead, use proven cost models like NICM in your own in-project cost estimates. That will provide another perspective on the mass dependence of instrument cost.

Question on Number Of Iterations

QUESTION (from a “Team-X” Probe):

What’s the number of iterations we can have with the design and costing teams…

**It makes a significant difference to our plans if we have any latitude to have more than a single design and costing exercise…
For example, one can envision one very rough costing exercise to narrow down 4 design options to two, and then a final design and costing round. Is that possible?
It would be unfortunate if teams restrict themselves from certain options, only to discover later that they could have had such options. Also, study managers at JPL and Goddard may *assume* that they are restricted from some options, when in fact they aren't.**

ANSWER:

Team X can do a single spacecraft mission study in about two days... If a second option is a variation on the first option (e.g., slightly heavier or more power hungry payload, change the propulsion system from bi-prop to SEP) it can be handled in the study with a third day. We are holding three days for your mission study. Furthermore, if you make small changes outside of Team X (e.g., drop or add an instrument) we can get a Team X systems engineer to update the sheets with the new information to get the correct mass and power and cost without holding another Team X session. You will not get a new configuration or a new report but sometimes you just need a new MEL and cost estimate. There is a good deal of flexibility with the instrument design team too. When you know what you would like to study then you, me and Amy should sit down and work out a Team X plan. … we have a good deal of flexibility in where to put the work but how much work we do is a fixed.