Cost Modeling
For Low-Cost Planetary Missions

(Presented to the 6th International Conference on Low-Cost Planetary Missions)

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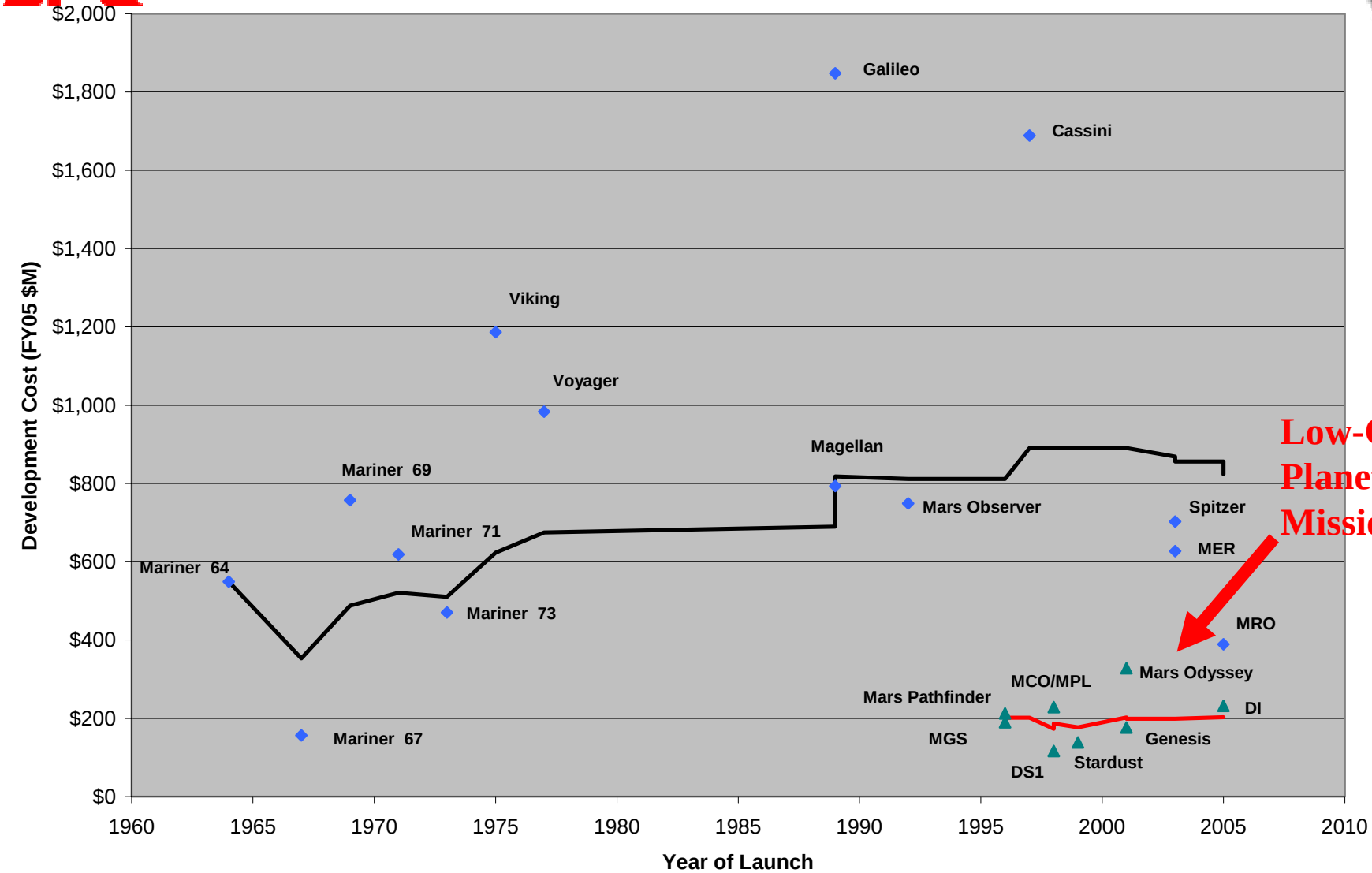
Agenda

- Overview of past planetary missions
- JPL low cost planetary missions (LCPM)
  - LCPM characteristics
  - Key factors to reduce total mission costs
  - Cost risk drivers example
- Cost modeling for LCPM
  - JPL formal cost estimation process
  - Methods and tools
  - Current available cost models
  - Cost model example
- Summary

Planetary Missions Overview

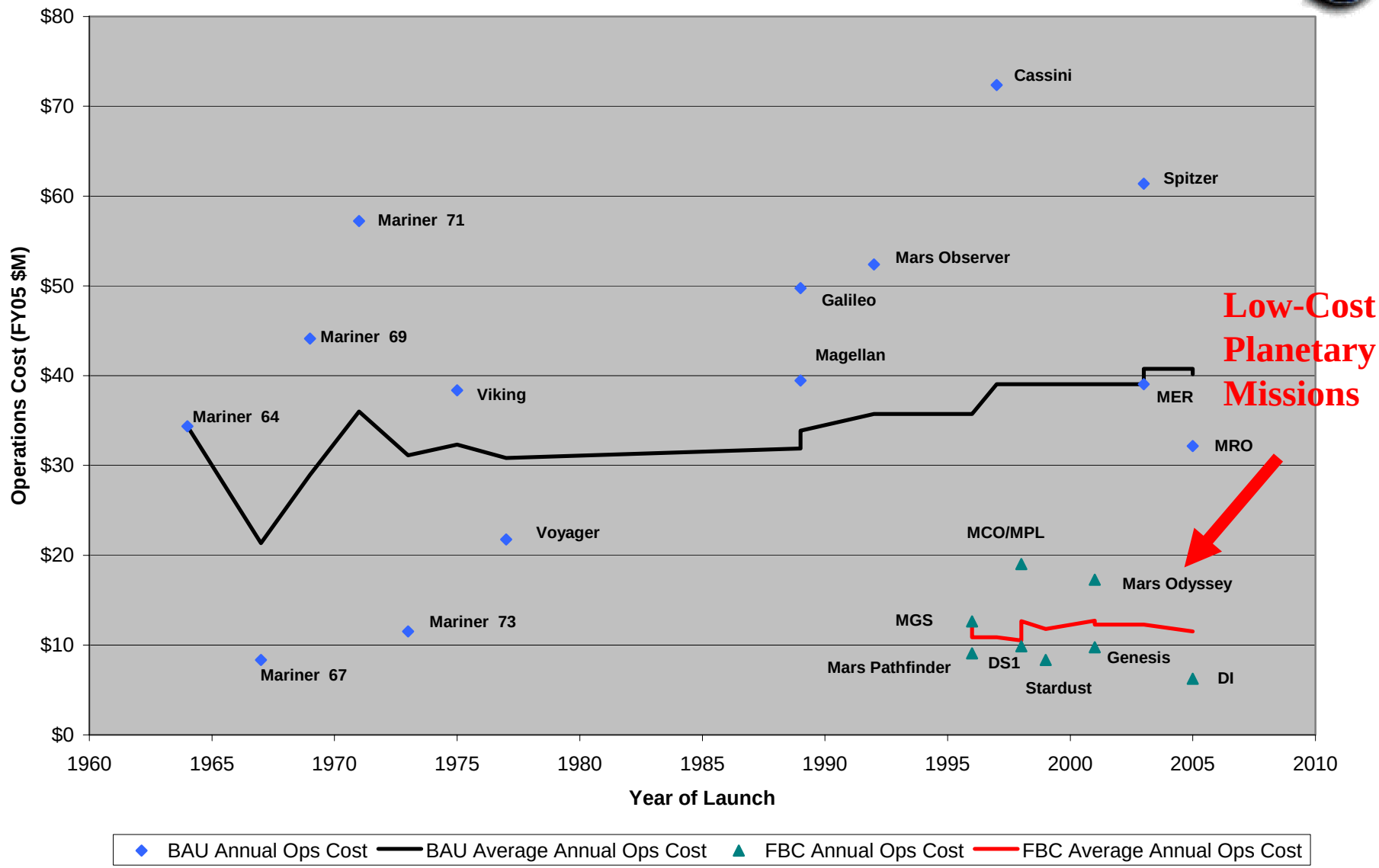
- Noncompetitive/directed missions (1964 – 2005)
  - Sole source w/o competition
  - No initial cost ceiling, cost growth was typical
  - More complex
  - New engineering and technology
  - Moderate to long development cycle (~ 5 to 12 years)
- Competed missions (Post 1992)
  - Mostly with a strict cost cap
    - Cost cap varies by NASA program office
  - Less complex
  - Inherited engineering/technology
  - Short development cycle (~ 3 years)

Development Costs (FY05 $M)



Note: Cost excluding launch vehicle; BAU: Business As Usual; FBC: Faster, Better, Cheaper

Operations Costs (FY05 $M)

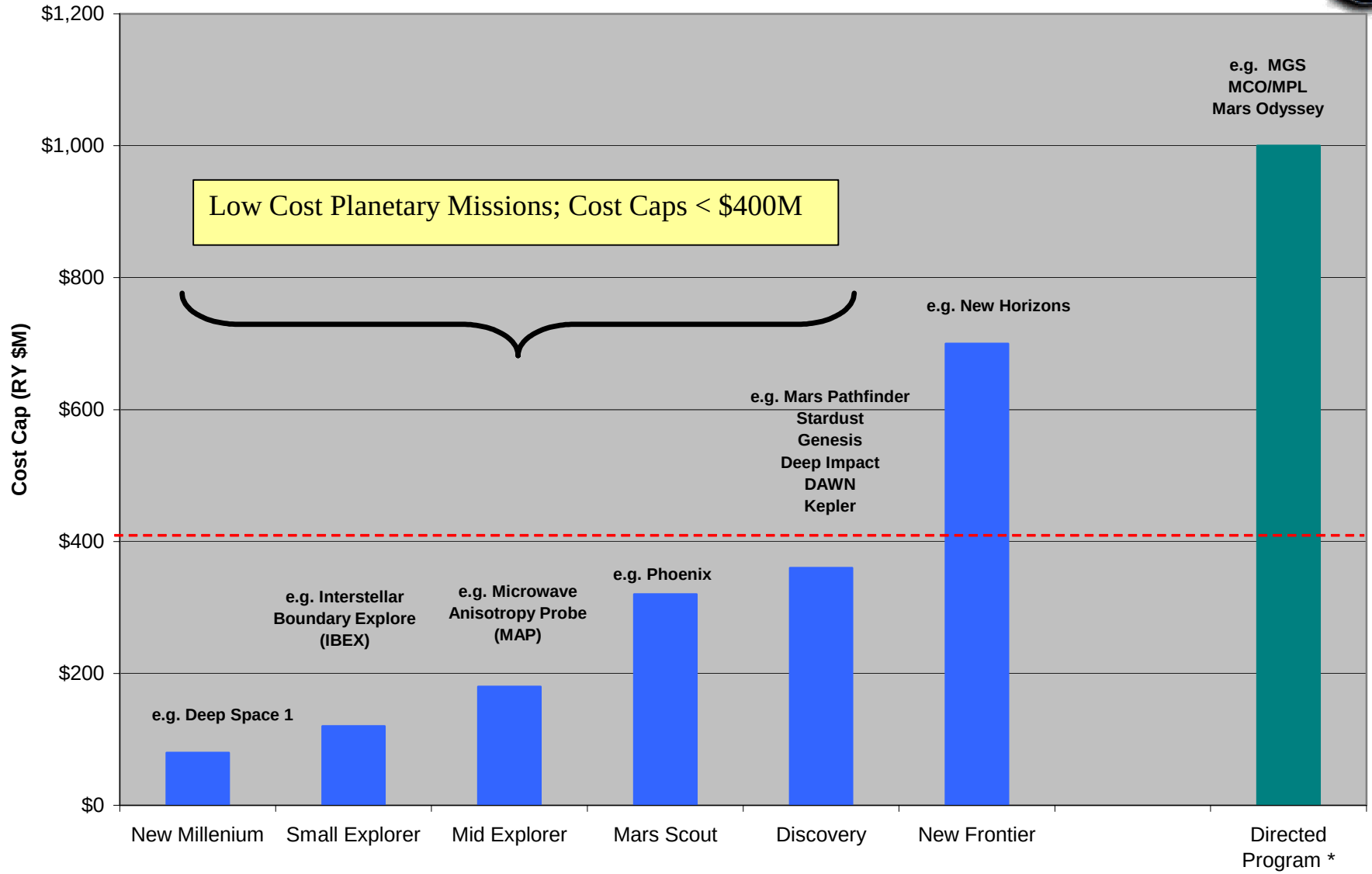


Note: BAU: Business As Usual; FBC: Faster, Better, Cheaper

JPL LCPM Missions

- Total project cost between $200M to $400M (w/o LV)
- Cost
  - Average development cost ~ $200M (vs ~$800M))
  - Average annual operations cost ~$10M (vs ~$40M)
- Schedule
  - Average development time ~ 3 years (vs 5 years)
  - Average operations time ~ 5 years (vs 7 years)
- Mostly competed missions (73%)
  - Strict cost cap, most cost caps < $400M (FY05)
  - Eight (8) LCPM Competed Missions
    - Mars Pathfinder, Deep Space 1, Stardust, Genesis, Deep Impact
    - DAWN, Mars Phoenix, Kepler
  - Three (3) LCPM Directed Missions
    - Mars Global Surveyor (MGS), Mars Odyssey, Mars Climate Orbiter/Mars Polar Lander (MCO/MPL)

Cost Cap by NASA Program Office



* Average Cost for all Directed Missions

Key Factors to Reduce Mission Costs (1 of 2)

- Less complex missions
  - No multiple objectives: Focused mission and science objectives
    - Fewer instruments & science teams/missions
  - No multiple flight elements and functionalities
  - Not operate in harsh environment
- Inherited engineering/technology
  - Minimize new/significant technology development: TRL< 5
  - Minimize new software or unvalidated software inheritance
  - More inheritance from previous missions:
  - Off-the-shelf equipments
    - Computers, operating systems, solid state storage, etc.
  - Less redundancy, less testing
- Short development cycle
  - ~ 3 years
  - Strategic stockpile/common buy for long lead items
  - Descope options

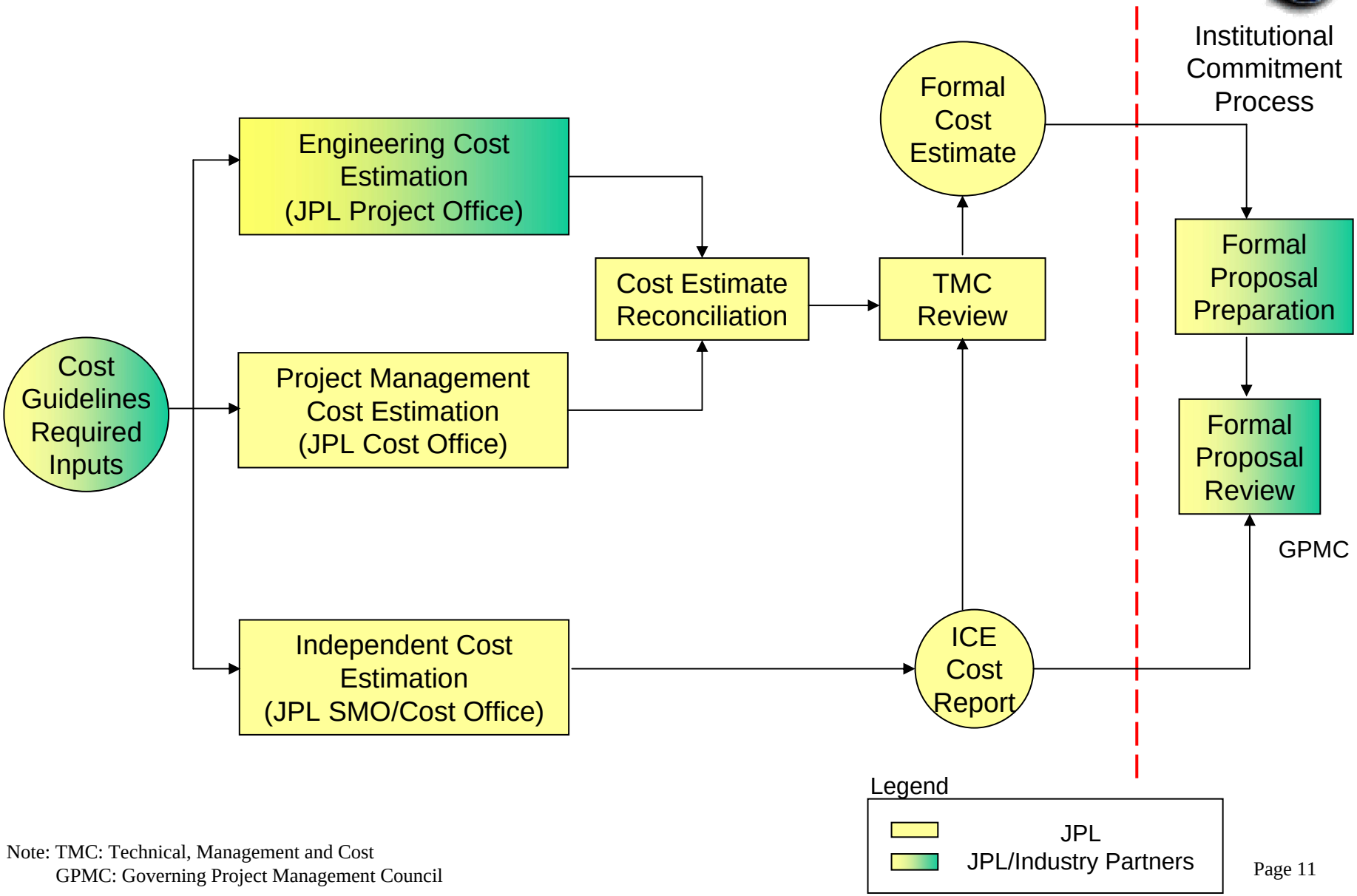
Key Factors to Reduce Mission Costs (2 of 2)

- Minimize new system architecture
  - Define level 1 requirements early in formulation phase
  - System with many ACS modes and deployments
  - Pointing control reliability requirements beyond state of the art
- Take advantage of Design-to-Cost and information technology during design and development
  - Concurrent engineering
  - Design tradeoff between cost vs schedule, performance, risk
  - Model driven design process
  - Automated fabrication from models
  - Continuous integration & testing
- Select experienced management team
  - Select experienced project manager and key project personnel
  - Select qualified/experience prime contractors
  - Limit # of organizational interfaces
  - Establish realistic technical and cost margins

Key Cost Risk Drivers - Example

	Mission #1	Mission #2	Mission #3
Complex Mission	-----	-----	Yes
New/Significant Technology Development	Yes	-----	-----
New Software Development	-----	-----	Yes
Low Technical Margin	-----	-----	-----
New System Architecture	-----	Yes	Yes
Inexperience Contractor/Capabilities Match	-----	Yes	Yes
Inadequate Programmatic/Cost & Schedule Margin	Yes	-----	-----
Multiple Interfaces	-----	-----	-----
Inexperience Management Team	-----	Yes	Yes
Cost Overrun %	**15%**	**35%**	**50%**

JPL Formal Cost Estimation Process



Note: TMC: Technical, Management and Cost
GPMC: Governing Project Management Council

Cost Modeling Approaches

- Engineering Cost Estimation
  - Grassroots
- Project Management Cost Estimation
  - Analogy/Parametric
- Independent Cost Estimation
  - Analogy/Parametric

Methods/Tools	Cost Models (1)	Cost Databases (2)	Concurrent Engineering (3)
Parametric	Yes	-----	Yes
Analogy	-----	Yes	Yes
Grassroots	-----	Yes	Yes

Note:
1. Cost Models: PMCM, NICM, PRICE, SEER
2. Cost Databases: System Cost Database, Subsystem Technical Cost Database, PCAT
3. Concurrent Engineering: Team X, Team P, Team G

Project Mission Cost Models

	Planetary Mission Cost Model (PMCM)	Advanced Product Design Team (Team X) Cost Model	NASA/ AIR Force Cost Model (NAFCOM)	Systems Evaluation and Estimation of Resources (SEER)	Parametric Review of Information for Costing and Evaluation (PRICE)	Unmanned Spacecraft Cost Model 8th Edition (USCM 8)	Small Satellite Cost Model (SSCM)
Sponsor/ Developer	JPL	JPL	NASA/ Air Force	Galorath Inc.	Price Systems Inc	Tecolote Research Inc.	The Aerospace Corporation
Applications	Planetary Missions	Planetary Missions	Planetary Missions/ Earth Orbiting Missions(1)	Planetary Missions/ Earth Orbiting Missions(1)	Planetary Missions/ Earth Orbiting Missions(1)	Earth Orbiting Missions	Earth Orbiting Missions
Cost Estimating Level	System and Subsystem Level	System and Subsystem Level	System and Subsystem Level	System, Subsystem, and Any Lower Level (2)	System, Subsystem, and Any Lower Level (2)	System and Subsystem Level	System and Subsystem Level
Users	JPL	JPL	NASA/ Air Force/ Commercial (3)	Commercial (3)	Commercial (3)	NASA/ Air Force/ Commercial (3)	NASA/ Air Force/ Commercial (3)

(1) Database contains a mixture of Planetary and Earth Orbiting Missions.
(2) Non CER based methodology that can apply to any WBS level.
(3) Need authorization from Government sponsoring agency.

Instrument Cost Models

	Technology/ Science Cost Model	Team X Instrument Cost Model	Scientific Instrument Cost Model (SICM)	Multi-variable Instrument Cost Model (MICM)	NASA/ AIR Force Cost Model (NAFCOM)	Passive Sensor Cost Model (PSCM)	NASA Instrument Cost Model (NICM)
Sponsor/ Developer	JPL	JPL	Goddard Space Flight Center (GSFC)	Goddard Space Flight Center (GSFC)	NASA/ SAIC	Air Force/ Tecolote Research, Inc.	NASA/ JPL
Applications	Planetary Missions/ Earth Orbiting Missions(1)	Planetary Missions/ Earth Orbiting Missions(1)	Planetary Missions/ Earth Orbiting Missions(1)	Planetary Missions/ Earth Orbiting Missions(1)	Planetary Missions/ Earth Orbiting Missions(1)	Earth Orbiting Missions	Planetary Missions/ Earth Orbiting Missions(1)
Cost Estimating Level	System, Subsystem, and Any Lower Level (2)	System, Subsystem, and Any Lower Level (2)	System Level	System Level	System Level	Subsystem Level	System and Subsystem Level
Users	JPL	JPL	NASA/ Industry(3)	NASA/ Industry(3)	NASA/ Industry(3)	Air Force/ Industry(3)	NASA/ Industry(3)

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Cost Risk Driving Parameters - Example

PMCM

System

- Management/Systems Engineering
- Integration & Test
- Product Assurance

% of S/C and P/L Hardware Costs

S/C

- ACS = f (pointing knowledge, mass, # of H/W types, heritage of design)
- C&DH = f (mass, processor speed, heritage of H/W and S/W design)
- Power = f (power source type, solar array type, beginning of life power, battery size)
- Propulsion = f (propulsion type, specific impulse, mass)
- Structure = f (mass, # of types of mechanisms, # of mechanisms)
- Telecom = f (power, sc antenna diameter, downlink data rate, bands, mass, redundancy

NICM

P/L

- Optics = f (mass, schedule, wavelength, electronic # of bands, TRL, max power)
- µwave = f (mass, schedule, power, TRL)
- Fields = f (mass, power, design life)
- Particle = f (mass power, data rate)

Summary

- Define low cost planetary missions
  - Describes LCPM characteristics
  - Provide key factors to reduce total mission costs
  - Identify cost risk drivers to reduce cost overruns
- Develop credible cost estimates
  - Employ formal cost estimation process
  - Apply proven process, methods and tools
  - Involve system engineers to capture cost modeling drivers