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Technology Portfolio Analysis

Presentation to SBIRS Program Office

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We Have Extended Systems Analysis Capability JPL Substantially

- **Objective Technology Prioritization**
  - Mission values, decomposition, requirements
  - Technology performance/cost assessment
- **Risk Assessment in the Conceptual Design Phase**
  - For fixed cost and risk tolerance level, what is the best investment among candidate technologies

Wouldn't it be Nice if We Had This Table?

Annual Technology Investment ($M)	Preferred Technologies	Missions Enabled	MEPAG Measurements Enabled	Comments	Technology Candidates (Different Pathway Mix; Sensitivity Analysis)
25	a	3	XX XX	Insufficient dollars to complete all technologies for mission X, resulting in measurements Y not being done.	XX XX
50	b c d e f	4 7 9	XX XX XX XX	Sensitivity of preferred tech #2 highly dependent on...	XX XX XX XX XX
75	a d e f g	3 4 7 9	XX XX XX XX	Reduction in 75M/yr budget by 20% would result in...	XX XX XX XX XX

Science Goals and Objectives

1	**Determine if Life Ever Arose on Mars** ➢ Determine if Life Exits Today ➢ Assess the Extent of Prebiotic Chemical Evolution
2	**Determine the Evolution of the Surface and Interior of Mars (ÒGeologyÓ)** ➢ Determine the nature and sequence of the various geological processes (volcanism, impact, sedimentation, alteration, etc.) that have created and modified the Martian crust and surface. ➢ Characterize the Structure, Composition, Dynamics and History of the Interior.
3	**Determine the Climate History for Mars** ➢ Characterize the Present Climate and Climate Processes ➢ Characterize the Ancient Climate and Climate Processes
4	**Prepare for Human Exploration** ➢ Acquire Martian Environmental Data Sets ➢ Conduct In-Situ Engineering Science Demonstrations ➢ Emplace Infrastructure for (Future) Missions

Science Value Calculation

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- ***Fundamental Assumption*: Science Value of a Mission = number of different types of science measurements addressed by that mission (whether partial or complete)**
  - **Baseline case assumed equal measurement priorities; discounted priority in sensitivity analysis**
  - **Updates reflect changes in Tech Pacts 11/13/02**
  - **Additional measurements made on Earth not counted in MSR total: sum of MSL and MSR measurements pro-rated in accordance with sample return versus in-situ measurement value per D. McCleese.**
- **Procedure**
  - **192 MEPAG science measurements assigned to 9 mission portfolio options**
  - **Counts for MSL and MSR totaled to address 3 cases:**
    - — Case 1 BASELINE: MSR vs. MSL science value distributed 70-30 per D. McCleese 11/18/02 to reflect MSR "grab-sample" vs. MSL mobility
    - — Case 2: MSR vs MSL science value distributed 60-40 per D. McCleese 11/18/02 to reflect a perhaps higher science value for MSL re: baseline
    - — Case 3: MSR vs MSL science value distributed 25-75 per J. Farmer 11/15/02 to reflect value of in-situ sampling variety through mobility of MSL.

Number of Possible MEPAG Measurements per Mission

Mission	Baseline MSR/MSL 70-30	Lower MSR/MSL ratio 60-40	Lowest MSR/MSL ratio 25-75
MSL	29*	39*	73*
VOL	14	14	14
POL	25	25	25
SAR	4	4	4
IMG	25	25	25
GMO	0	0	0
TEL	0	0	0
MSR	68*	58*	24*
WLD	25	25	25

***Pro-rated values; e.g., 70-30 = 70% of 97 measurements =68 for MSR and 30% for MSL=29.**

Mission Information

Mission	Full Name	Earliest "Technology Possible" Launch Date	Mission Cost thru phase C/D; excl. technology development $ M (real)
MSL	Mars Science Laboratory	10/2009	750
VOL	Mars Volcanology Rover	9/2009	600
POL	Mars Polar Layer Deposit Rover	10/2011	1000
SAR	Mars Advanced Orbiter SAR Mission	10/2009	490[b]
Imaging	Mars Advanced Orbiter Imaging/Atmospheric Mission	11/2011	830[b]
GMO[a]	G. Marconi Orbiter	7/2007	102
Telesat[a]	Small Mars Telesat	7/2007	351
MSR_GB	Mars Sample Return Ground Breaking	2013	1400
Wildcat	Mars Wildcat	11/2011	890

Comments
a –Telesat orbiter will only be developed if G. Marconi Orbiter is not developed
b – Assumes one year of operations

Technology Path Network

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	Precision Landing, kilometers	Impact Attenuation Landing Survivability, m	Hazard Avoidance, meters	On-orbit Science - Wavelength, meters	On-orbit Science - Resolution, meters/pixel	Forward Planetary Protection - Measurement Time, hours	Forward Planetary Protection, No. org.	Surface Ops-Sample Char. TRL	Surface Ops-Sub Surface Access, meters	Surface Ops-Mobility, Meters/Sol	Surface Ops-Sample Handling, ppm	Back Planetary Protection, microns	Telecom, Mars Proximity, Megabits/sec	Telecom, Mars to Earth, Megabits/sec	Mars Orbit Rend. Capture time, Sols	Multimission survivability. Sols	Approach and Instrument Placement, Sols	Mars Ascent Vehicle, C
MSL	1 | *	2	3	⊘	⊘	6	⊘	8	⊘	10	11	⊘	⊘	⊘	⊘	16	17	⊘
VOL	⊘**	⊘**	⊘**	⊘	⊘	⊘**	⊘**	8	⊘	10a | **	⊘	⊘	⊘*	⊘	⊘	⊘**	⊘	⊘
POL	X | MSL	X | MSL	X | MSL	⊘	⊘	X | MSL	⊘	8a	9	10b	⊘**	⊘	X | MSL,*	⊘	⊘	X | MSL	⊘	⊘
SAR	⊘	⊘	⊘	4	⊘	⊘	⊘	⊘	⊘	⊘	⊘	⊘	⊘*	⊘***,*	⊘	⊘	⊘	⊘
Imaging	⊘	⊘	⊘	⊘	5	⊘	⊘	⊘	⊘	⊘	⊘	⊘	⊘*	14 | ***	⊘	⊘	⊘	⊘
GMO[b]	⊘	⊘	⊘	⊘*	⊘*	⊘	⊘	⊘	⊘	⊘	⊘	⊘	13 | *	⊘a	⊘	16a	⊘	⊘
Telesat[b]	⊘	⊘	⊘	⊘*	⊘*	⊘	⊘	⊘	⊘	⊘	⊘	⊘	13 | *	⊘a	⊘	16a	⊘	⊘
MSR_GB[c]	X | MSL	X | MSL	X | MSL	⊘	⊘	X | MSL	7	⊘	⊘	⊘	⊘	12	⊘	⊘	15	⊘	⊘	18
Wildcat	X | MSL	X | MSL	X | MSL	⊘	⊘	X | MSL	7	8a	9a	⊘	11a | MSL	⊘	X | MSL	⊘	⊘	X | MSL	⊘	⊘

m | n

m= reference number for technology data, "X" if no additional requirement
n= dependency on another technology requirement, left blank if no dependency

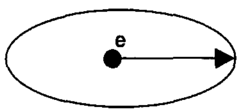
Comments

* - Dependant on MRO
** - Dependant on MER
*** - Dependant on industry or other government center

a – Does not include High Gain Antenna, listed as enhancing
b – U.S. Telesat orbiter will only be developed if G. Marconi Orbiter is not developed
C – No technology development for Returned Sample Handling is represented here as that is being handled separately from the rest of the project. MSR has also expressed the need for some sort of orbiting attribute (preferably a Telesat) but since this attribute is not required to be one of the two Telesats listed here this requirement is not captured in this study.

1 - Data Sheet for Precision Landing

Landing ellipse axis



Attribute Definition:
Semi-major axis of landing ellipse in kilometers

4. Estimate the budget profile in 3 year blocks (Real M$)

'03-'05	'06-'08	'09-'11	'12-'15
5	0	0	0

5. Enter total technology development cost for this technology (2002 dollars)

Point estimate (best guess): $ M

or

Range estimate (low to high): ___ - ___ $M

1. Estimate length of semi-major axis for this technology assuming task succeeds with probability 100%; (pick one)

Point estimate (best guess)

or

Range estimate (low to high): 5 - 10

or

Estimate e

e	P(x<e)
	0
	.25
	.50
	.75
	1.00

2. Enter your estimate of actual probability of success that technology will be developed (0-100%).

95%

3. If the technology task fails, what is the best state-of-the-art likely to be achieved? (default—use current SOA)

100km

Notes, Assumptions:

Assumes ability to land at up to 2.5 km above MOLA geoid (mean altitude) included

[Optional] This technology applies to following mission(s) (check all that apply if known, otherwise leave blank):

☐VOL	☐SAR	☐MSR
☐ROV	☐IMA	☐WLD
☐RVL	☐SSC	☐SAB
☐ MAG	☐POL	☐SCT[1]

Baseline Results: MSR Groundbreaker (Sample Return) Science Path

Technology Investment ($M/yr)	Technology Candidates	Missions Enabled	MEPAG Meas. Enabled, N	Comments	Tech. Candidates (Pathway Mix; Sensit. Analysis)
25 Technology Cost Profile (RY $M): [21, 21, 21, 3.3, 3.3, 3.3, 0, 0, 0, 0, 0, 0]	<u>Volcanology Rover</u> ❑ Sample characterization ❑ Mobility at 160-200m <u>Imaging Orbiter</u> ❑ On-orbit science resolution (wavelength) ❑ Telecom network, Mars to Earth Technology Cost = $73M	❑ Volcanology Rover ❑ IMG orbiter Mission Cost = $1430M	Max. Possible N = 39 E(N) = 30.2 Std. Dev. = ±10.9 ~16% of all possible measurements	Other single missions possible (e.g., MSR) with lower expected total science value due to higher technology development risk	Same result for 60-40 and 25-75 paths

Baseline Results: MSR Groundbreaker (Sample Return) Science Path

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Technology Investment ($M/yr)	Technology Candidates	Missions Enabled	MEPAG Meas. Enabled, N	Comments	Tech. Candidates (Pathway Mix; Sensit. Analysis)
50 Technology Cost Profile (RY $M): [49.5, 49.5, 49.5, 20, 20, 20, 2, 2, 2, 0, 0, 0]	Mars Science Lab □ Precision landing □ Impact attenuation □ Hazard avoidance □ Forward planet. protect., time □ Sample characterization □ Mobility at 230-450m □ Sample handling, contam. □ Multimission survivability □ Approach/Instr. Placement Volcanology Rover □ Sample characterization □ Mobility at 160-200m Imaging Orbiter □ On-orbit science resolution □ Telecom network, Mars to Earth Mars Sample Return □ Precision landing □ Impact attenuation □ Forward planet. protect., time □ Forward planet. protect., # org. □ Back planet. protection □ Mars orbit rendezvous □ MAV Technology Cost = $214M	□ MSL □ VOL □ IMG □ MSR Mission Cost = $3580M	Max. Possible N= 136 E(N) = 43.2 Std. Dev. = ±27.3 ~23% of all possible measurements	POL enters at $55M/yr Wildcat does not enter due to higher prob. of success for VOL technologies than Wildcat; Wildcat has same max. science value but uncertainty lowers its expected value.	Same result for MSR—MER path In Situ—MSL Path adds SAR and drops MSR because more uncertainties in MSR technologies reduces expected science value more than SAR would.

MSR-Groundbreaker Path: Technology Budget Sensitivity

Increasing Technology Budget ⟶

	$25M/yr	$35M/yr	$45M/yr	$50M/yr	$55M/yr	$65M/yr	$75M/yr
Mars Science Lab			△	△	△	△	△
Volcanology Rover	△	△	△	△	△	△	△
Polar Layer Deposit Rover			△		△		
SAR Orbiter		△				△	△
Imaging Orbiter	△	△	△	△	△	△	△
Mars Sample Return				△	△	△	△
Wildcat							

△ = in the optimal portfolio

25-75 Path: Technology Budget Sensitivity

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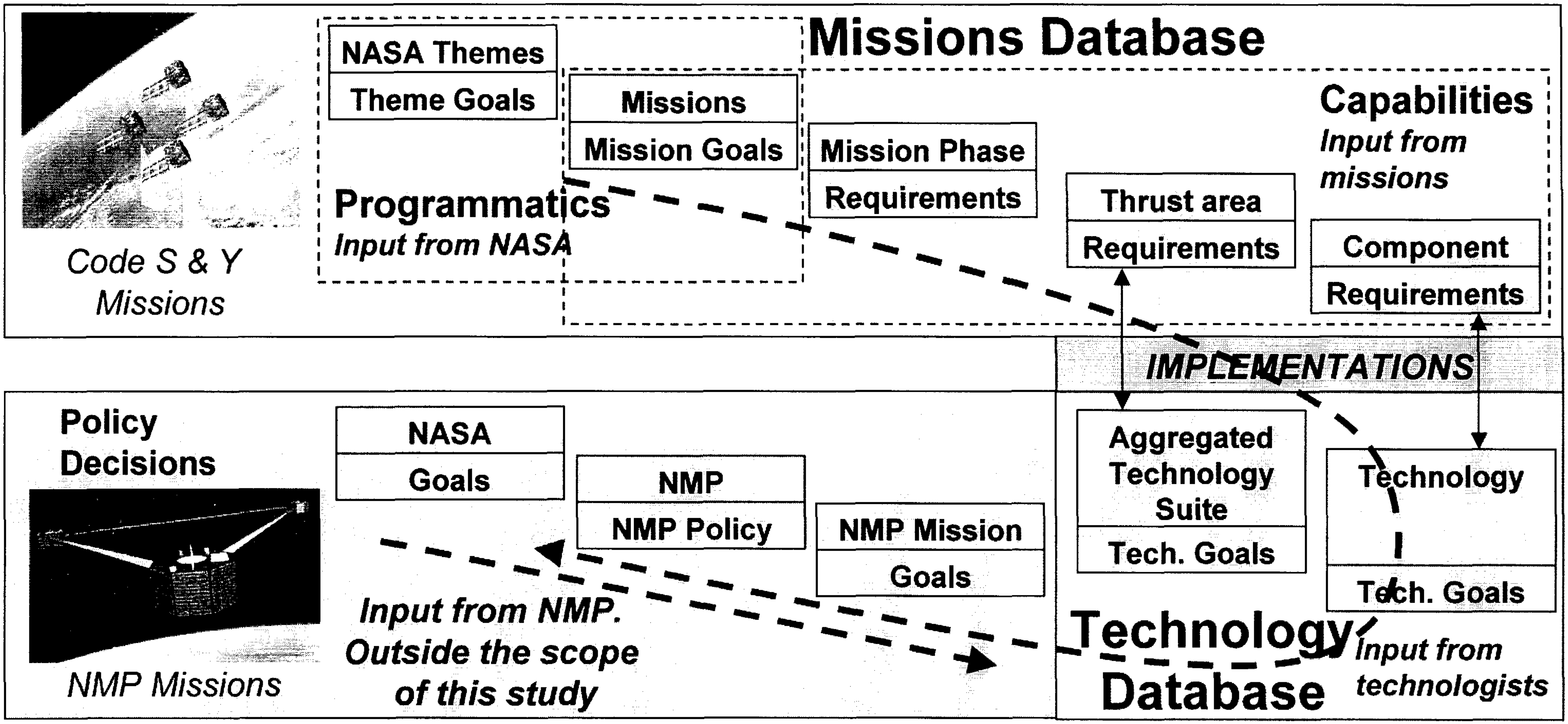
Increasing Technology Budget →

	$25M/yr	$35M/yr	$45M/yr	$50M/yr	$55M/yr	$65M/yr	$75M/yr
Mars Science Lab			△	△	△	△	△
Volcanology Rover	△	△	△	△	△	△	△
Polar Layer Deposit Rover			△		△	△	△
SAR Orbiter		△		△	△	△	△
Imaging Orbiter	△	△	△	△	△	△	△
Mars Sample Return							
Wildcat						△	△

△ = in the optimal portfolio



Technology Ranking Approach

- ➢ Relate Mission Goal values to Theme Science goals and NASA goals
- ➢ Relate Mission Capabilities values to Mission Goal values
- ➢ Relate Technology values to the values of the enabled capabilities
- ➢ Relate NMP technology portfolios and mission values to the qualified technologies and NMP mission goals

Technology Database

Calculation of Technology Utilities through Comparison of Technology Goals and Required Capabilities

Mission Requirements	Metric(s) Name	Value	Units	Data Source	Value
5.4.2.1: Acquire Relative Bearing	Bearing Knowledge	1	arcmin	TPF-10, p. 3	3.5
	Bearing Rate Knowledge	10	arcsec/s	TPF-10, p. 3	
	Field of Regard	10x10	deg	TPF-10, p. 3	
5.4.2.2: Acquire Relative Range	Operational Range	15-100	m	TPF-10, p. 3	3.5
	Range Knowledge	1	cm	TPF-10, p. 3	
	Range Rate Knowledge	1	mm/s	TPF-10, p. 3	
. . .	. . .				. . .

5.4.2 Fine Formation Flying, Position Acquisition	
5.4.2 Capability Value:	10.4
Technology Deadline:	PDR

Applicable Technologies:	Metric(s) Name	Value	Units	Data Source	Contacts/References: Organization	Primary Contact	Technology Readiness: Current TRL	Date (Ready for TRL-6 transfer)	Cost (To TRL-6 transfer)	Technology Utility 5.4.2.1: Performance	Completeness	Ulitity	Technology Utility 5.4.2.2: Performance	Completeness	Ulitity
Current State-Of-The-Art: ARX (ST-6): LAMP	Range Accuracy	2.5	cm	B. Pain	JPL	Curtis Padgett	6			0	0.0	0.0	0	0.0	0.0
	Bearing Accuracy	0.1	deg												
MSTAR	Resolution	a few	nano-m	Rec #6908	JPL + USC + Pacific Wave Ind.	S. Dubovitsky 818-354-9796	2	2005	$3M	0	0.0	0.0	1	0.9	0.9
	Operational Range	a few	km	Rec #6908											
Autonomous Formation Flying Sensor (AFF)	Range Knowledge	2	cm	Rec #8308	JPL	M. Gudim 818-354-6987	4	2004	$15M	1	1.0	1.0	0	0.0	0.0
	Operational Range	30-1000	m												
	Bearing Knowledge	1	arcmin												
	Field of Regard	70	deg (cone half-angle)												
. . .	. . .				. . .		. . .								

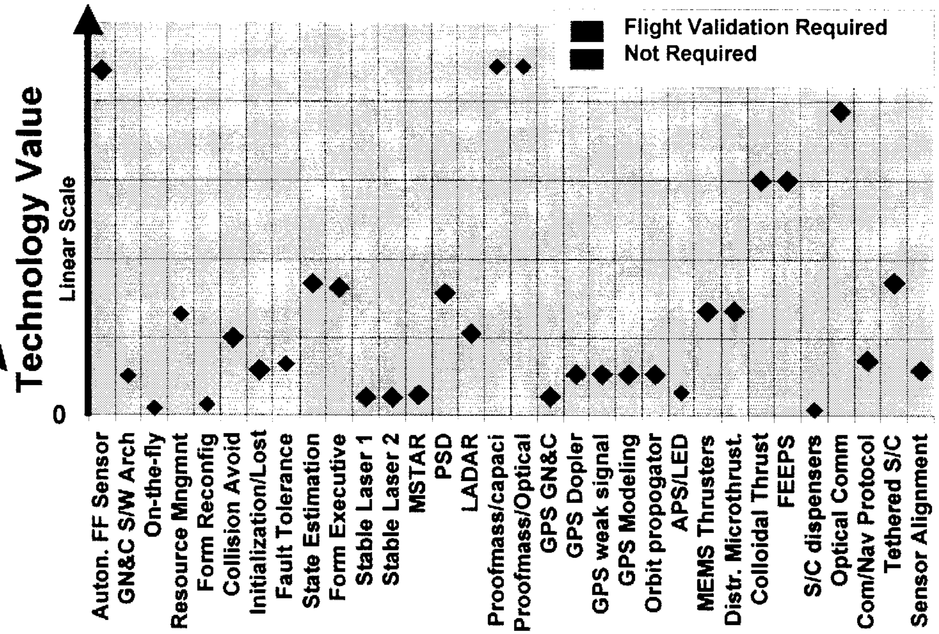
Supporting Decisions

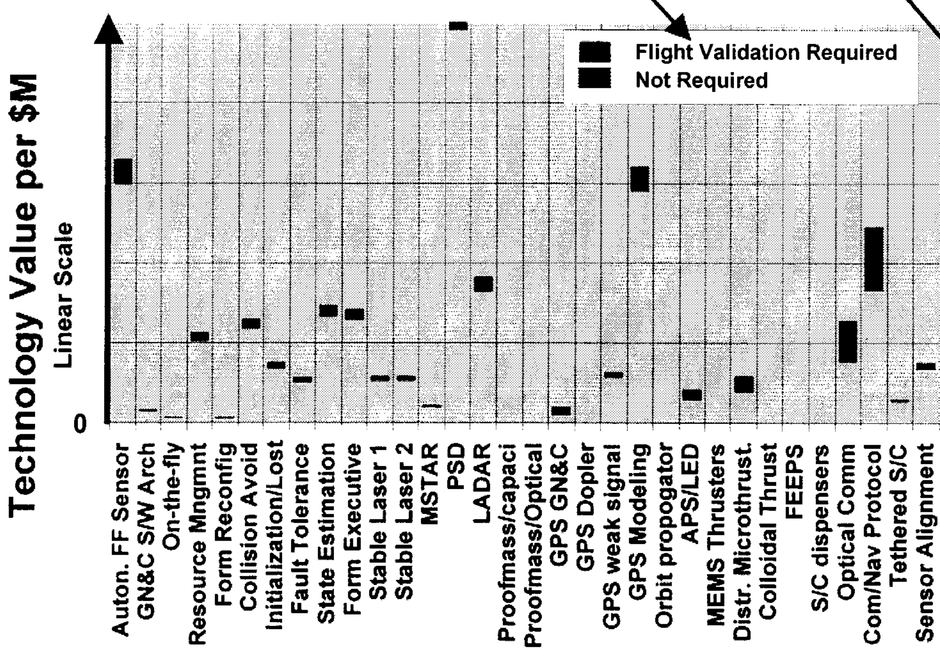
Examples of results

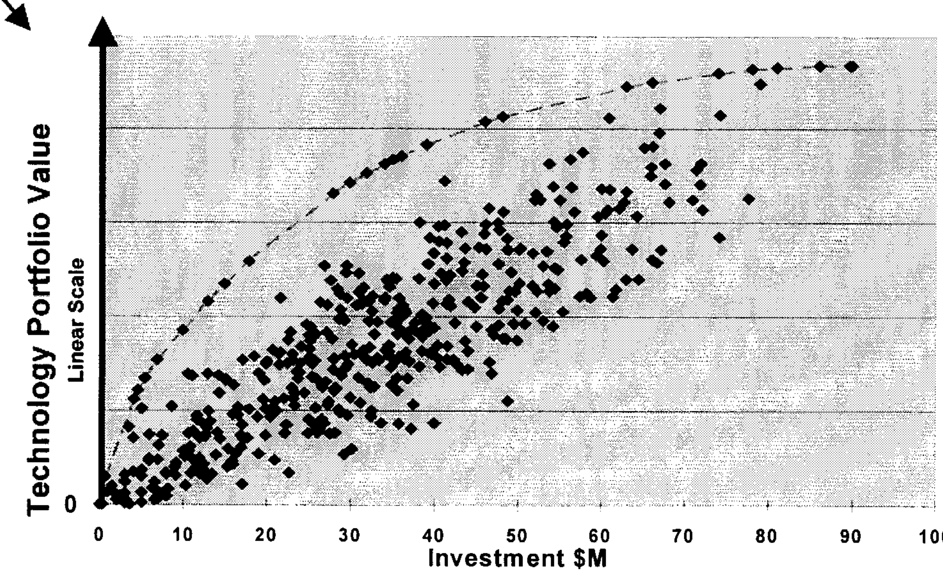
Ranking of Technology Capability Areas

Return on investment for Technology Portfolios

Return on investment for individual technologies

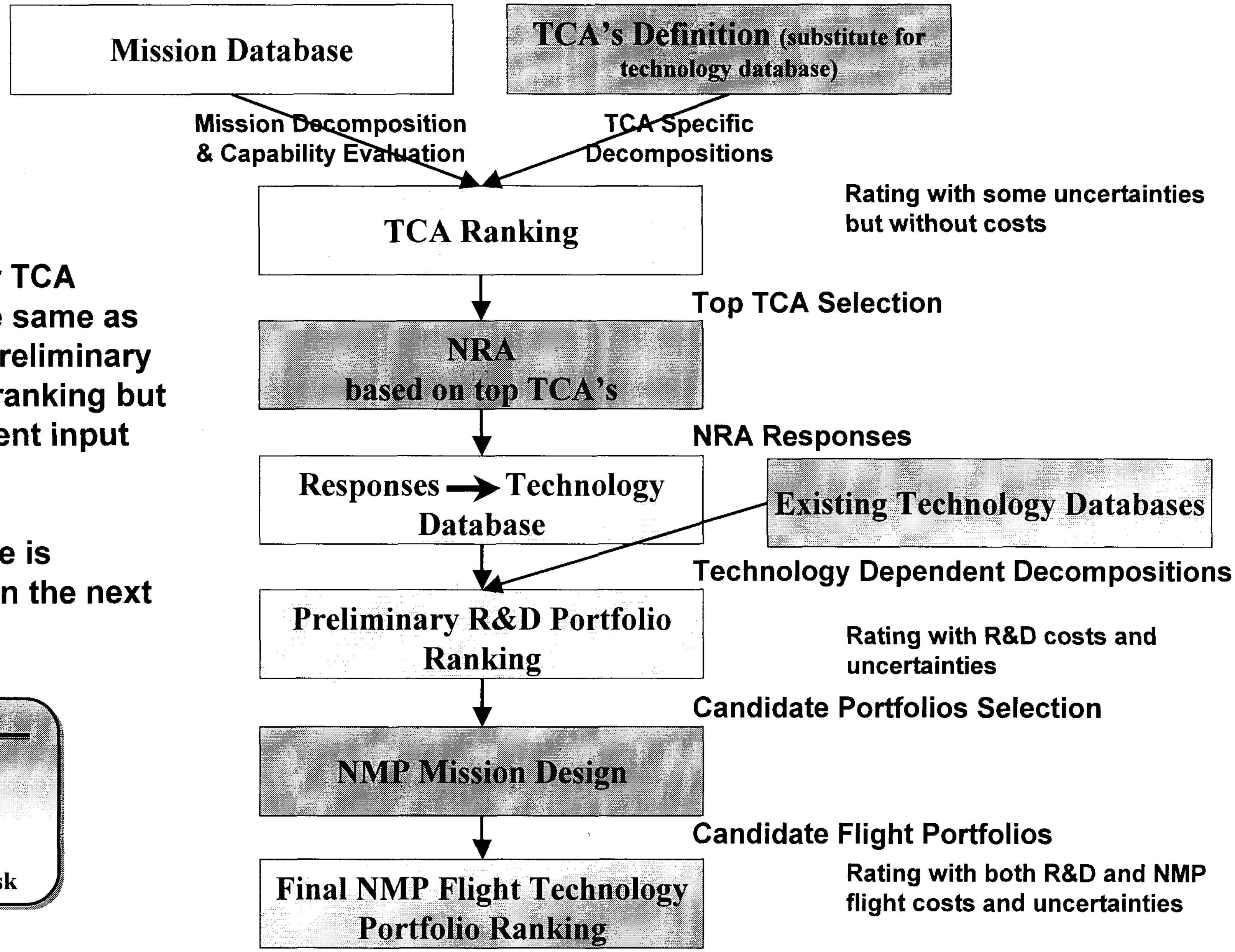






See next slide for abbreviation list

End-to-End NMP Technology Portfolio Selection



Procedures for TCA ranking are the same as those for the Preliminary R&D portfolio ranking but they use different input database

Each procedure is decomposed on the next slide