Architecture Assessments

Assessment Protocol

- Science scoring team
  - -- separate scores for planet detection and astrophysics
- Technical scoring team
- For comparison of architectures:
  - -- normalize to equal total collecting area
- Results presented at team meeting for review
- Some architectures adjusted to optimize scoring
- Score revised to reflect adjustments

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Technical Scoring

- Goal of technical scoring:

  -- Define each concept sufficiently to rank them as potentially *realizable* space systems
  -- A preliminary assessment aimed at rank-ordering based on engineering/technology attributes

- Methods

  1. System "complexity" assessment (scored worksheet)
  2. Engineering team assessment by JPL technical areas (scored and rank-ordered)
  3. Risk/consequence assessment (semi-quantitative, based on technology needs)
  4. ROM cost (OSC tools)
  5. Schedule and Future Heritage

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Complexity Assessment

- Technical metrics evaluation; weighted score using 6 design attributes
  - Each concept scored on relative difficulty in each area
  - Subset of design features where assessment could be done now
    - -- Areas equally weighted
      - System complexity
        - Total number of platforms
        - Number of independent platform designs
      - Baseline maintenance method
        - Monolith/structure/free-flyer
        - Free-flyer position accuracy if applicable
      - Operating temperature for optics/FPAs
      - I&T difficulty (qualitative estimate)
  - Net score in all areas used to rank concepts relative to each other
    - -- Individual scores meaningless

<u>RANK</u>: 1. ASA 2. Rotational HT Imager 3. Redundant Linear Array
4. Book Design (ff) 5. Snapshot HT Imager
(Laser Trapped Mirror not evaluated)

Engineering Team Assessment

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- Engineering team evaluation at OHP concept review meeting
- Weighted score by Engineering-only team members using JPL technical attributes
  - -- New technology
  - -- Risk
  - -- Reliability and Robustness
  - -- Life cycle cost
  - -- Heritage to future missions

RANK:

1. Apodized Square Aperture
2. Snapshot and Rotational Hypertelescope Imagers
3. Redundant Linear Array
4. Book Design

- Numbers 2-4 very close; ASA viewed as significantly higher
- *LTM not evaluated*

Risk/Consequence Assessment

- Technology "areas of concern" (see below) identified at Engineering team review Oct '00
- Subset of this list used for semi-quantitative risk assessment
    - -- Low/moderate/high risk
    - -- Low/moderate/high impact
    - -- Each concept scored in each area
    - -- Net scores normalized to [-1,1] for both risk and consequence (not all areas applied to all concepts; 8-11 items used for each concept)

Large Optics	Quiet Structures
Precision Deployable Structures	Tethers
Formation Flying	LOS Pointing
Detectors	Nulling Interferometry
Coronagraphy/Phase Masks/Apodization	NanoNewton Thrusters
On Orbit Construction/Servicing	

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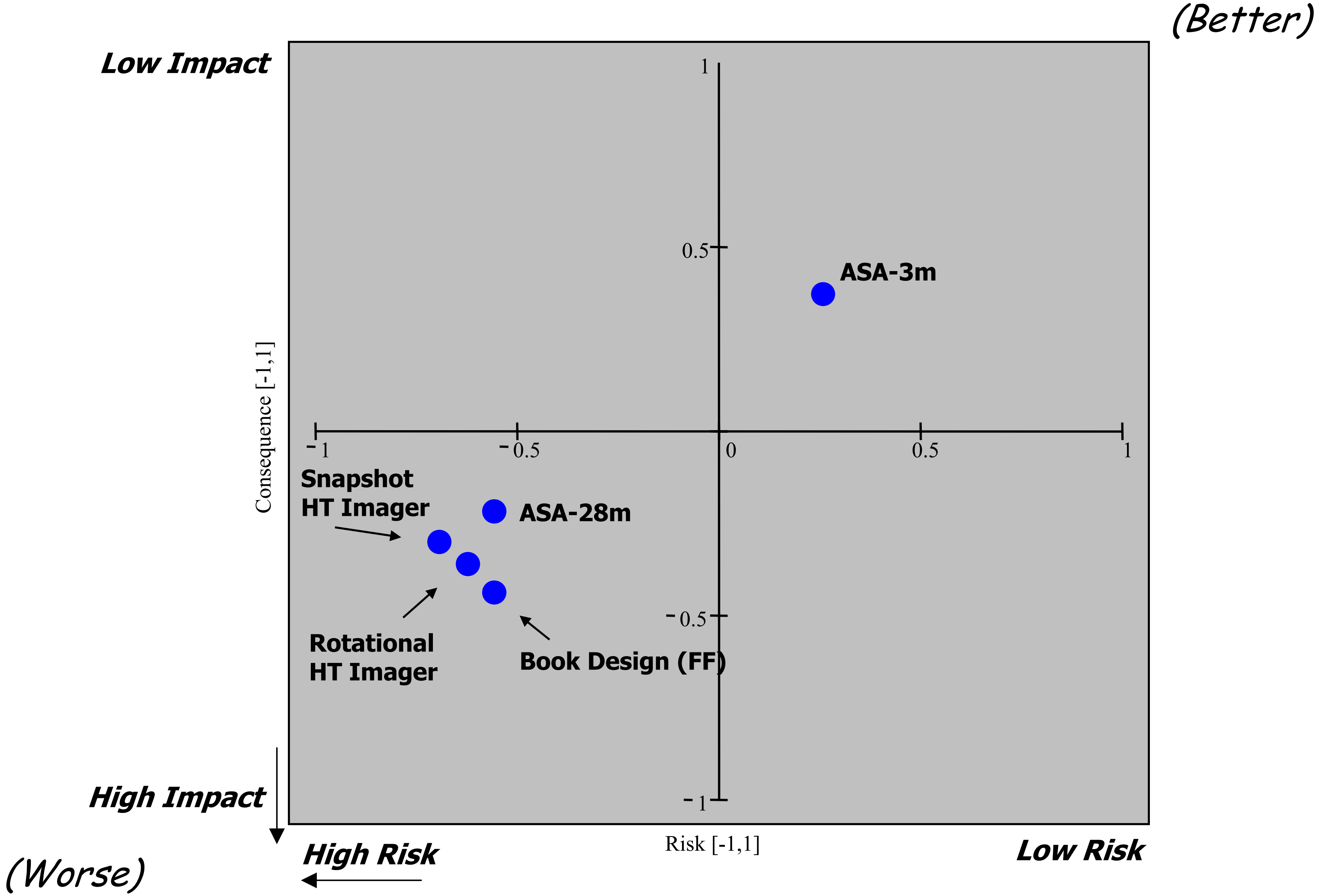
Risk/Consequence for TPF Concepts

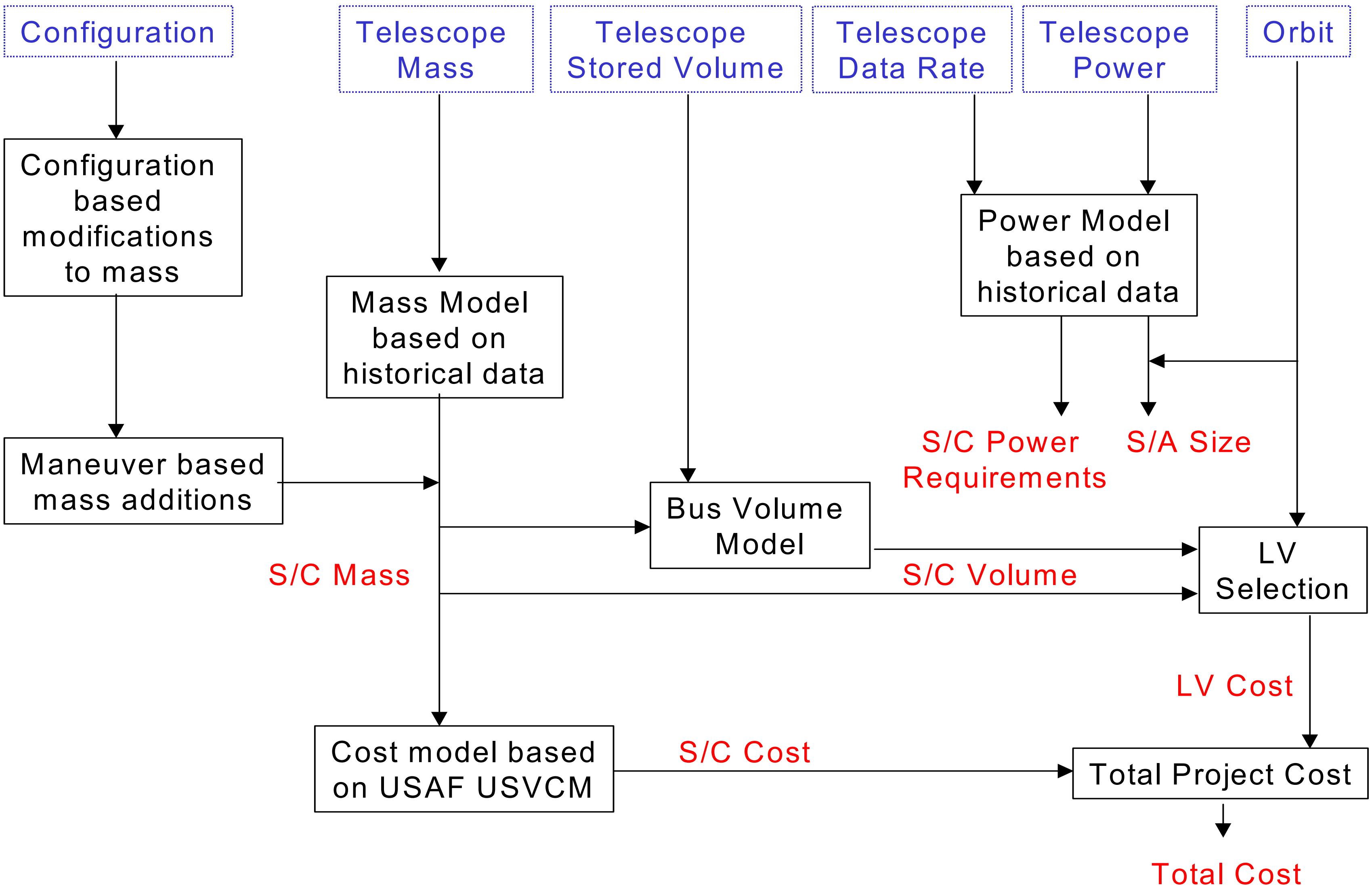
(Better)



ROM Cost Assessment

- Concepts were ranked on a relative basis using a costing tool developed by OSC
  - -- Purpose is to evaluate concepts using a common tool and methodology
  - -- No importance attached to absolute numbers
- Tool details: multiple components including spacecraft size/mass, launch vehicle, ground segment and ops, RDT&E factors
- Multiple mass models
- Cost model based on USAF unmanned space vehicle cost model

Cost Model Flow



Relative Costs

ASA (3m "TPF-lite", visible)	0.3
ASA (8m visible)	0.7
Rotational HT Imager	0.8
Book Design (free-flyer)	1.0
Snapshot HT Imager	1.2
ASA (28m visible-IR)	1.5

Schedule and Future Heritage

- Qualitative schedule assessment using SIRTF, SIM, NGST, TPF (BD) nominal mileposts (at 2010, 2012)

- Relative schedule ranking:
  ASA(3m)
  ASA(10m)
  TPF (BD, ff)
  Rot HT [close to BD]
  ASA(28m)
  Snapshot HT [current form: far]
  LTM

- Overlap of ASA and HT designs → significant schedule spread

- Heritage to future missions: LF and PI
  -- HT, LTM, and BD assigned highest ranking
  -- ASA relatively low

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Science Performance Assessment

- All candidates must meet minimum requirements of Design Reference Program - scoring ranks relative performance for these
- Planet Score
- Astrophysics score

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Planet Science Scoring

Score = 5/(resolution in arcsec)

+ 4*(spectral resolution)

+ 6*(distance in parsecs for standard earth detection in 10 hours)

+ 50*(fractional uv coverage in one snapshot)

+ 10 (for a nuller without imaging)

- 20 (if reconfiguration required for each star searched)

- 20 (if reconfiguration required during each observation)

+ (20,10,50) for observation in (thermal, reflected, both)

+ (15,20,10,10,10,12,5,5,8) for coverage of bands of (O_3, O_2, CO_2, CH_4, NH_3, H_2O, H_2, CO, Water ice)

Maximum score = 550

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Astrophysics Science Scoring

Score = 30*(λmax/λmin)

+ baseline in meters * [1 (visible) or 0.1 (infrared)]

+ FOV width in pixels / 5

+ 0.1 * (spectral resolution)

+ 6*(distance in parsecs for standard earth detection in 10 hours)

+ 10 (for a nuller without imaging)

- 20 (if reconfiguration required from planet search)

- 20 (if reconfiguration required during each observation)

Maximum score = 500

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Science Scoring – Results
(Planetary sci: 75% Astrophys: 25%)

	Planetary Sci	Astrophys	Weighted total
Densified Pupil Hypertelescope	455/500	412/550	444
Laser Trapped Mirror	400/500	550/550	437
Book Design	365/500	371/550	366
Redundant Linear Array	300/500	287/550	297
ASA	300/500	340/550	310
Occulters	250/500	520/550	317

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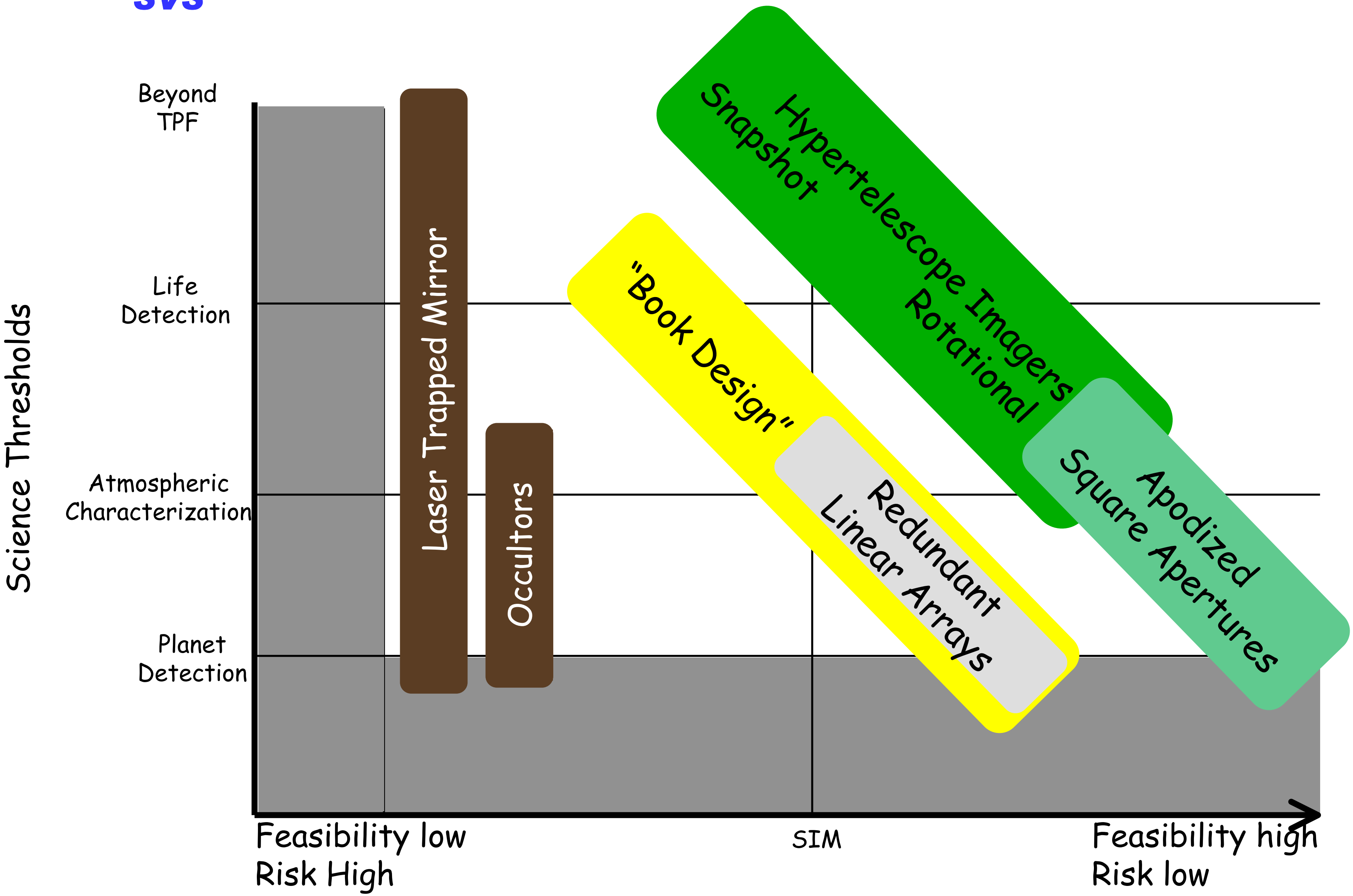
Scorecard of Assessments

	Filled Apertures w/Square Apodization	Densified Pupil Arrays	Redundant Linear Arrays	"Book Design"	Laser Trapped Mirrors	Occultors
Science Performanc	4	1	4	3	2	5
Technology	1	2	3	4	5	n/r
Schedule	1	4	3	2	5	n/r
ROM Cost	1	3	n/r	2	n/a	n/r
Future Heritage	3	1	n/r	2	n/a	n/r

Comparison of Concepts



Architecture Priority List

1. Apodized Square Apertures
2. Hypertelescope Imagers
3. Redundant Linear Arrays
4. Interferometric nullers (e.g., "Book Design")
5. Laser trapped mirrors
6. Occultors

Precursors

TPF Precursors

- Science precursors
  - -- Previously proposed
  - -- New opportunities
- Mini-TPF concepts
- TPF technical precursors

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Present Precursors

Mission	Launch	Results	Status
SIRTF	2002	~2005 Large Exo-Zodis	Selected
COROT	2004	<2007 ~10 Hab.Earths	Selected
Kepler	2006?	<2009 ~400 Hab.Earths	Decision 01/01
Eddington	<2012	<2015 ~50 Hab.Earths	'Reserve'
GAIA	<2012	<2013 ~10 Hab.Earths	Selected
SIM	2009	<2010 ~10 Hab.Earths	Selected

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Additional Precursors

Mission	Results
2-3 m Apodized Square Aperture	~2010 Imaging of Earths
TREASURE Transits of Nearby Earths	<2010

Why not:

~10 M_{earth} planets from intensive radial velocity programs

RV = 2 - 3 m/s for K star

$\sigma(V_r)$: goal 1 m/s

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Mini-TPF Concepts

- Each architecture can be scaled to accomplish part of the TPF Design Reference Program
- For connected structure implementations, a mini version serves as a complete technology precursor
- For the free-flyer implementations, a mini version based on a connected structure can accomplish part of the DRP with reduced risk and delay
- Mini-TPF science goals:
  - -- Detect earths for nearby stars
  - -- Detect Jupiters (and solar system analogues) for all TPF program candidates

Precursor Recommendations

- It is ***critical*** to have an estimate of the frequency of earth-like planets, around typical neighborhood stars, in order to optimize the design of TPF

Direct method – detect habitable candidates

-- Statistically significant transit survey

-- Radial velocity search for high-mass earths

- Indirect method – detect solar system analogues (massive planets in outer system)

-- Enhanced radial velocity searches

-- New precursor TBD

-- Mini-TPF TBD

Phase II Plans

Phase II Plans

- Refine design realism for selected concepts
  - -- Detailed subsystem modeling and analysis (continuation of work already started for apodized square aperture and DPHT concepts)
  - -- Integrated end-to-end models
- Refine technology risk and cost risk/trades for concepts
  - -- Technology survey (TRL levels, concept-specific) already in work
  - -- Additional cost parametrics & trades
- Investigate precursor options

Conclusions and Recommendations

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Conclusions and Recommendations

- Develop Apodized Square Aperture architecture on several possible scales - in visible and infrared - as potentially quickest, cheapest TPF realization
- Develop Hypertelescope Imager architectures, as most promising for eventual very high resolution TPF realizations, scalable to Life Finder and Planet Imager
- Define earth frequency through precursors
- Develop mini-TPF options as TPF alternatives
- Continue investigation of Laser Trapping as enabling technology for future ultra-large apertures