NRC Workshop on NASA Instruments, Observatories, & Sensor Systems Technology

National Academies' Beckman Center, Irvine, CA

3/29/2011

Panel 2: Observatories

Tony Hull

L-3 Integrated Optical Systems

Tinsley, Brashear and SSG

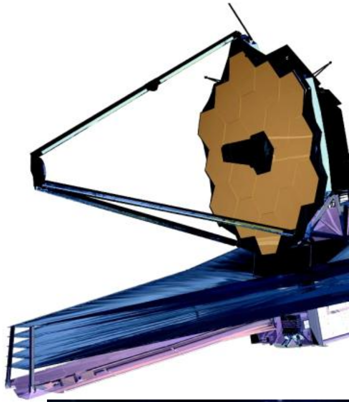
and

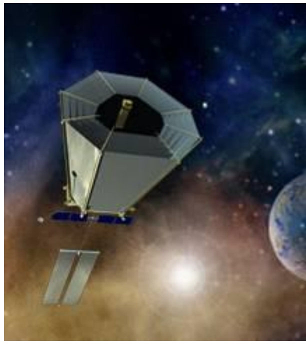
Adjunct Professor of Physics and Astronomy

University of New Mexico

Perspective

- Adjunct Professor of Physics & Astronomy: University of New Mexico
- L-3 IOS (Tinsley, Brashear, SSG)
- 3 decades of experience with NASA Programs in Industry and at NASA (JPL) including
  - Program Manager of JWST Optical Fabrication
  - NASA Technologist Terrestrial Planet Finder (TPF) (Coronagraphic Approach)
  - Management team of Aerospace Optical companies
- Recent visits to ESTEC and European Prime Contractors (Nov and Dec 2010)

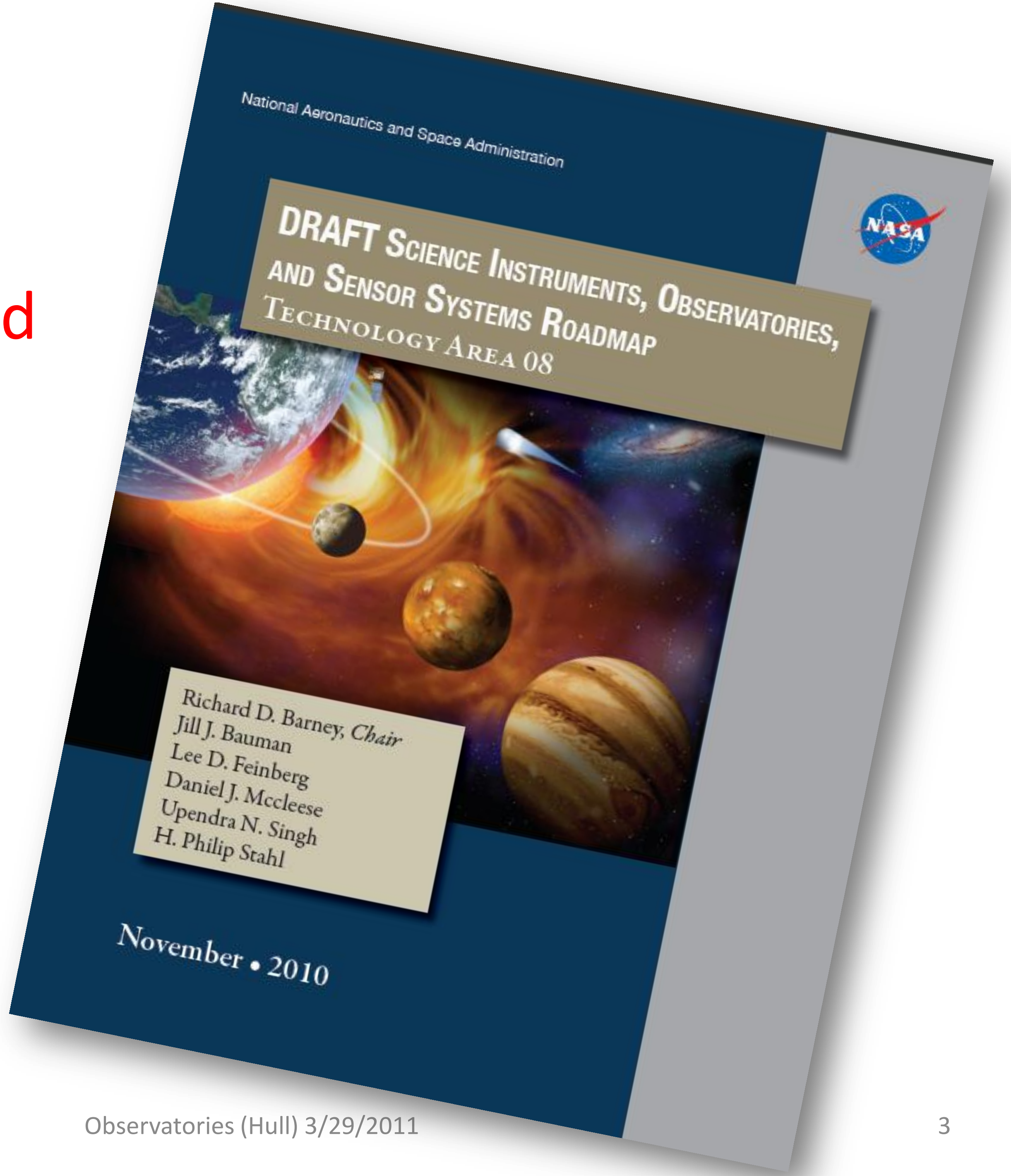




Ideas represented here are mine, and may not reflect a position of either L-3 or UNM

SIOSS = Science Instruments Observatories and Sensor Systems

New Worlds, New Horizons



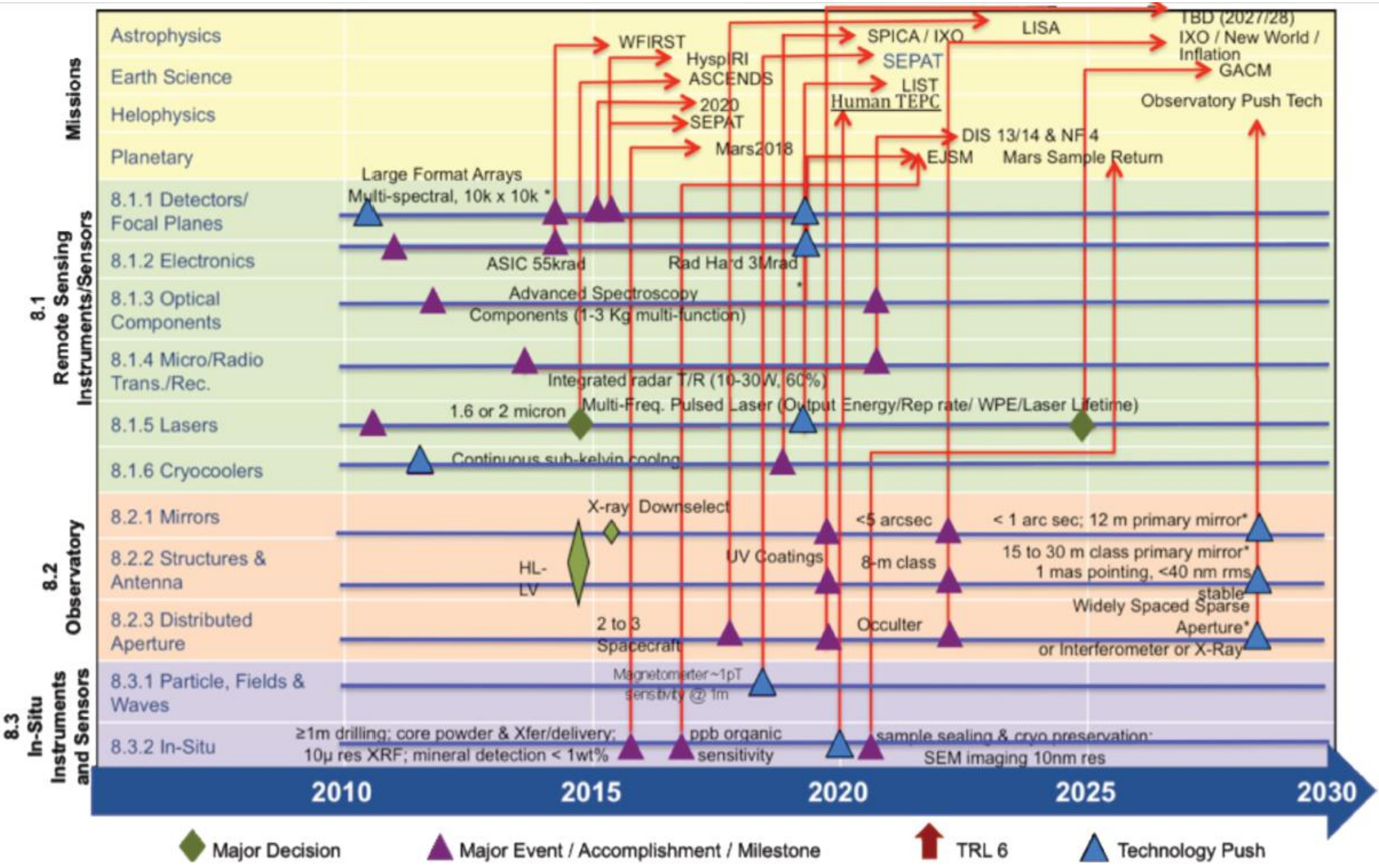
National Aeronautics and Space Administration

DRAFT SCIENCE INSTRUMENTS, OBSERVATORIES, AND SENSOR SYSTEMS ROADMAP
TECHNOLOGY AREA 08

Richard D. Barney, *Chair*
Jill J. Bauman
Lee D. Feinberg
Daniel J. Mccleese
Upendra N. Singh
H. Philip Stahl

November • 2010

SIOSS Technology Area Strategic Roadmap



Missions

Astrophysics

Earth Science

Helophysics

Planetary

WFIRST

HyspIRI

ASCENDS

2020

SEPAT

Mars2018

SPICA / IXO

SEPAT

LIST

Human TEPC

LISA

TBD (2027/28)

IXO / New World / Inflation

GACM

Observatory Push Tech

DIS 13/14 & NF 4

EJSM

Mars Sample Return

8.1 Remote Sensing Instruments/Sensors

8.1.1 Detectors/ Focal Planes

Large Format Arrays

Multi-spectral, 10k x 10k *

8.1.2 Electronics

ASIC 55krad

Rad Hard 3Mrad

8.1.3 Optical Components

Advanced Spectroscopy

Components (1-3 Kg multi-function)

8.1.4 Micro/Radio Trans./Rec.

Integrated radar T/R (10-30W, 60%)

8.1.5 Lasers

1.6 or 2 micron

Multi-Freq. Pulsed Laser (Output Energy/Rep rate/ WPE/Laser Lifetime)

8.1.6 Cryocoolers

Continuous sub-kelvin cooling

8.2 Observatory

8.2.1 Mirrors

X-ray Downselect

<5 arcsec

< 1 arc sec; 12 m primary mirror*

8.2.2 Structures & Antenna

HL-LV

UV Coatings

8-m class

15 to 30 m class primary mirror*

1 mas pointing, <40 nm rms stable

8.2.3 Distributed Aperture

2 to 3 Spacecraft

Occulter

Widely Spaced Sparse Aperture*

or Interferometer or X-Ray

8.3 In-Situ Instruments and Sensors

8.3.1 Particle, Fields & Waves

Magnetometer ~1pT sensitivity @ 1m

8.3.2 In-Situ

≥1m drilling; core powder & Xfer/delivery;

10μ res XRF; mineral detection < 1wt%

ppb organic sensitivity

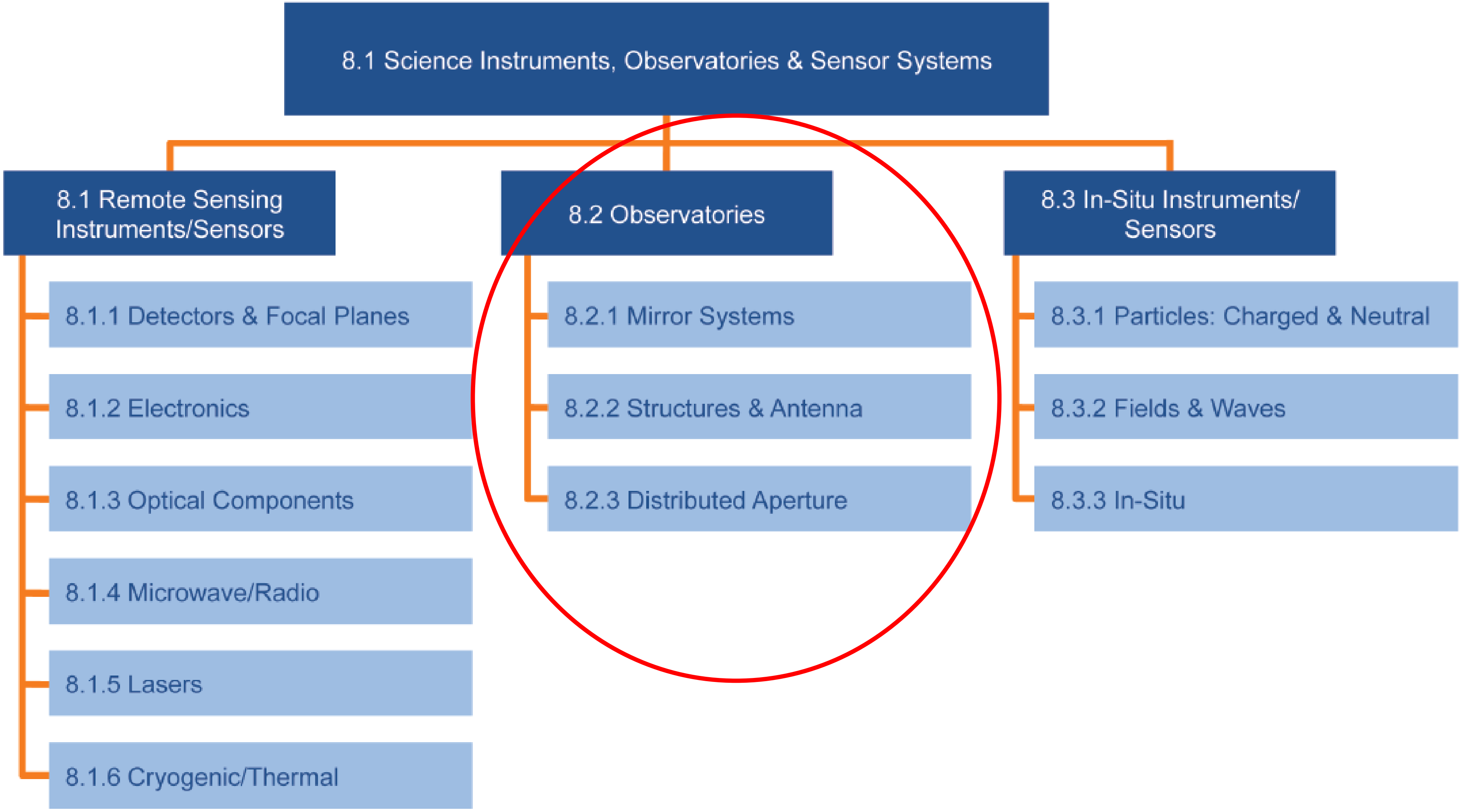
sample sealing & cryo preservation;

SEM imaging 10nm res

2010 2015 2020 2025 2030

◆ Major Decision ▲ Major Event / Accomplishment / Milestone ⬆ TRL 6 △ Technology Push

SIOSS Technology Area Breakdown Structure



8.1 Science Instruments, Observatories & Sensor Systems

8.1 Remote Sensing Instruments/Sensors
- 8.1.1 Detectors & Focal Planes
- 8.1.2 Electronics
- 8.1.3 Optical Components
- 8.1.4 Microwave/Radio
- 8.1.5 Lasers
- 8.1.6 Cryogenic/Thermal

8.2 Observatories
- 8.2.1 Mirror Systems
- 8.2.2 Structures & Antenna
- 8.2.3 Distributed Aperture

8.3 In-Situ Instruments/ Sensors
- 8.3.1 Particles: Charged & Neutral
- 8.3.2 Fields & Waves
- 8.3.3 In-Situ

Figure 1. *Technology Area Breakdown Structure*

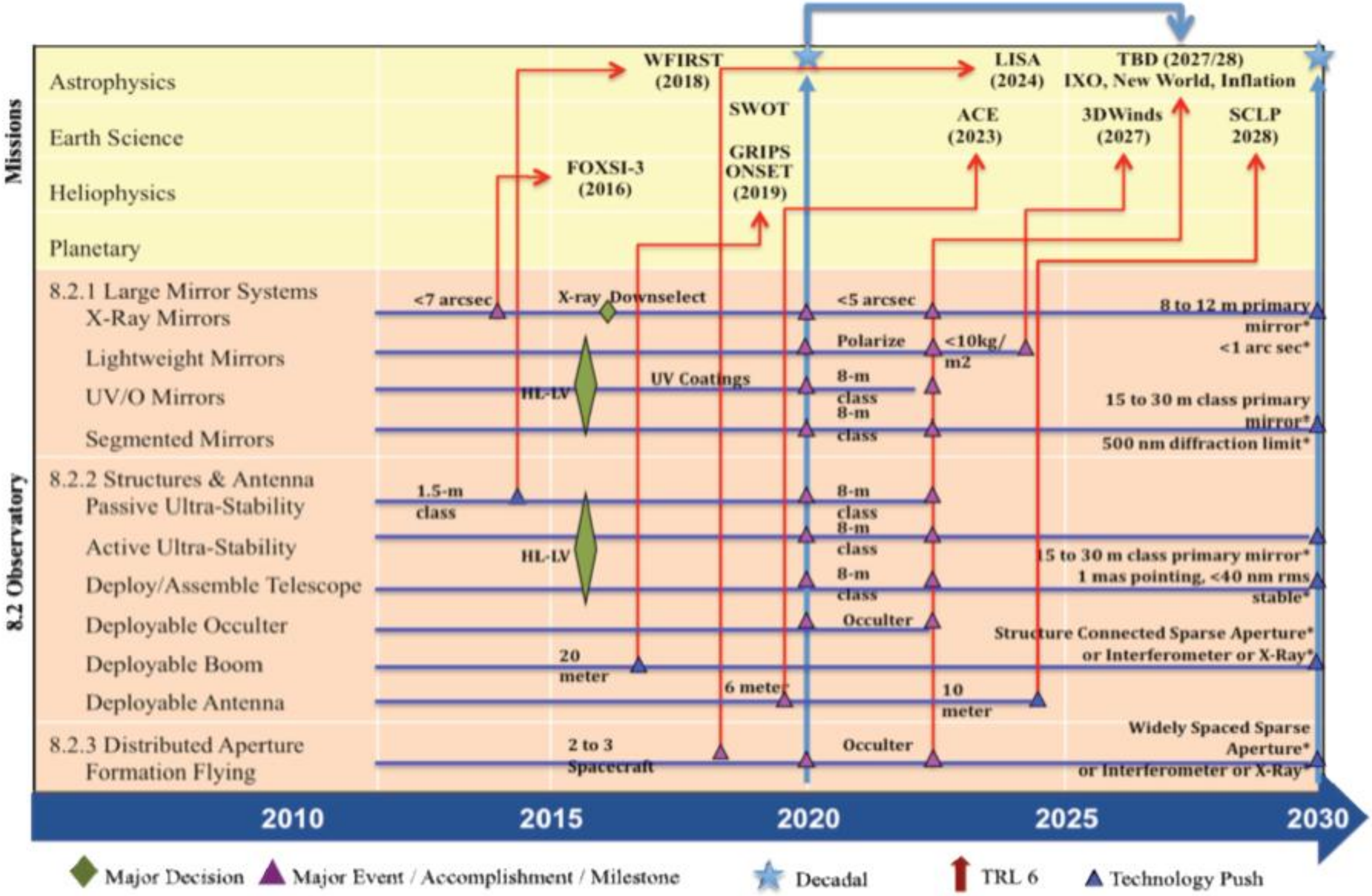


Figure 4. *SIOS Observatory Technologies Roadmap*

General Observations on Technology Development

"First to get cut"

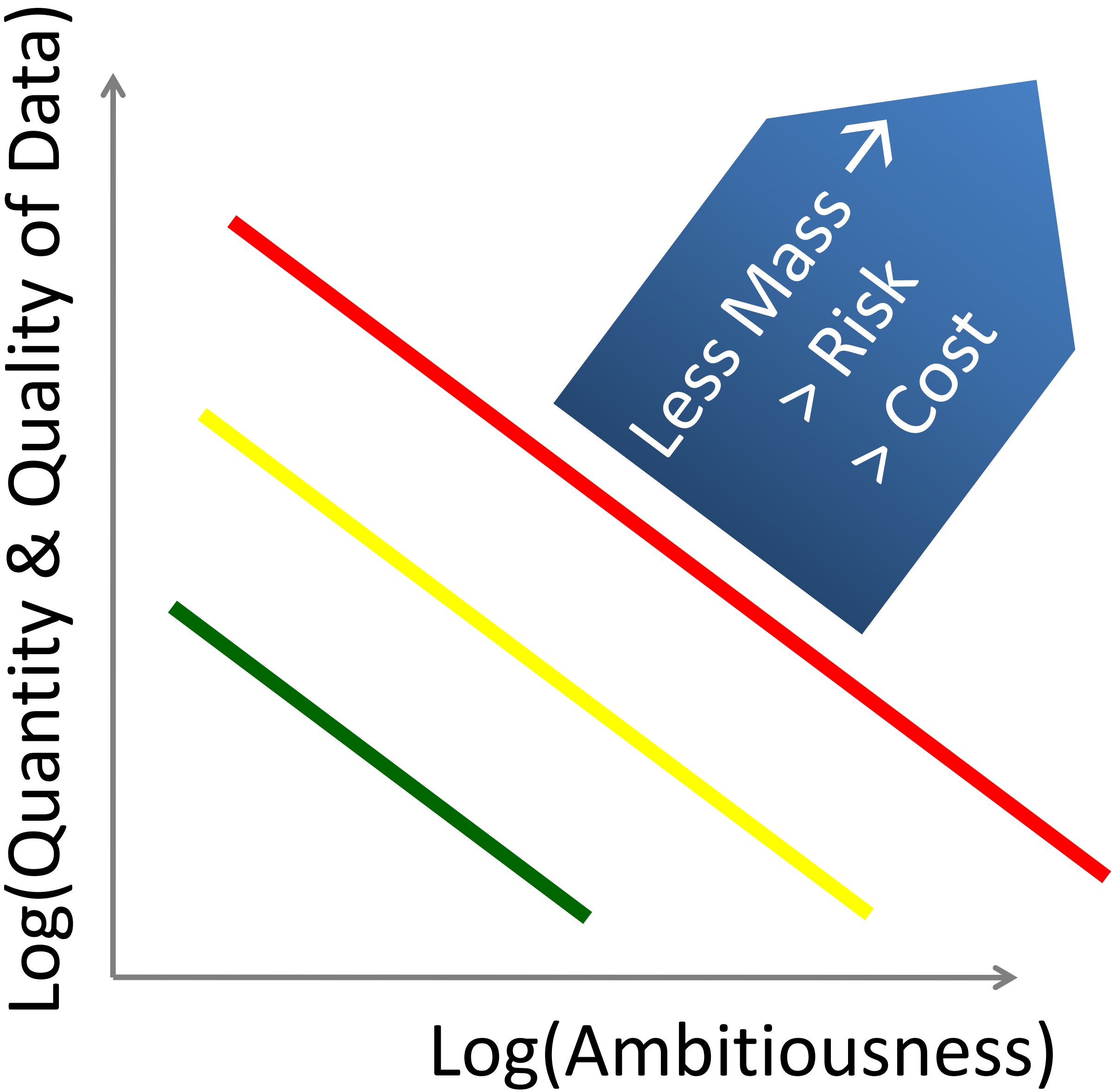
- "Hard to provide a solid funding stream to really move something forward."
- "Little stuff is ok, but once bigger money is needed, hard to sustain."

Hope in "the approach NASA Chief Technologist Bobby Braun"

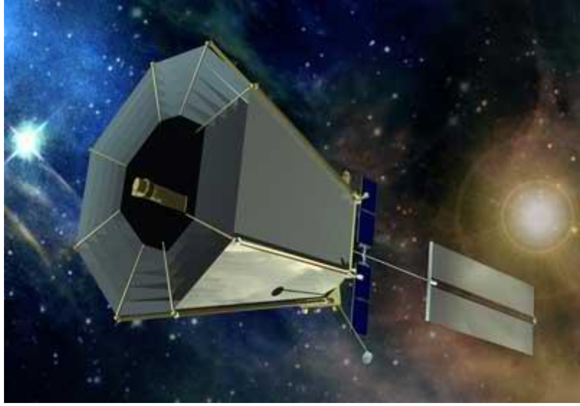
- "Provides general guidelines to solve the grand challenges and technology roadmaps"
- "Start a bunch of small things
  - Mature them through a funnel process
  - Keep the good ones that really improve"

Personal correspondence Gary Matthews

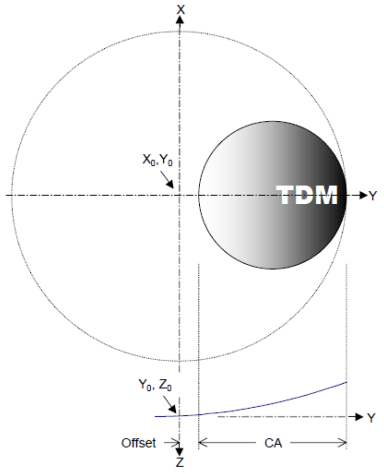
Mission Requirement



Example of NASA Technology Development



- TPF was well funded initially
- One of the perceived highest risks 10 years ago was making a very smooth, very large (8m-10m) off-axis monolithic primary mirror
- Technology Demonstration Mirror was to evaluate/develop our state of readiness with a subscale mirror (~2m) containing all the remaining attributes.



- In general, "getting something into real production takes both solid funding and infrastructure that may not be there."

A Perspective & Concerns

- The exact attributes of the plan are to me secondary
- My experience from both within NASA and from industry leads to greatest concern center about stability of administrative plans, and associated funding

Personal Concern 1

- Early stabilization of the minimal science requirement
- Definition of a realistic budget
  - Can we and will we?
- A convergent process for stabilization of baseline technical approach with redundant capabilities
  - TPF example: Too much technical competition, without commensurate NASA technology for evaluation and selection, is counterproductive
- Funding continuity (start/stop is very expensive) and drives talent from the field

Personal Concern 2

- Each new observatory mission must do more to be justified → Observatories are getting more expensive and budgets will not grow commensurately
- International contributions are being increasingly sought
- With international collaboration, will NASA keep a balance of NASA Center work and Industrial work?
- Is the critical mass of space work sufficient to maintain both NASA Centers and supporting Aerospace Industry as we know it?
- If Industry is endangered, are future NASA Observatories technically robust?

Personal Concern 3

- Space 2.0: The basis of growth in numbers of new spaceborne systems appears to be international
  - demand for earth imaging (agriculture, weather, maritime, forest fire support, etc.)
- Technology is driven by funding and matured by practice!
- Protectivism (ITAR) has unexpected consequences, and as implemented, may undermine, not enhance our position of leader in Space

Personal Concern 3

The consequence of Protectivism (ITAR) applied with a heavy and unpredictable hand:

- US industry will not be asked to participate
- If US technology is not available to Space 2.0 requirements, Europe or the Orient will develop it, and will have the current practice.
- Access limited to a declining market only weakens US technical readiness for new observatories.
- Technology will be lost, not enhanced.
- Greater future dependence on offshore technology.

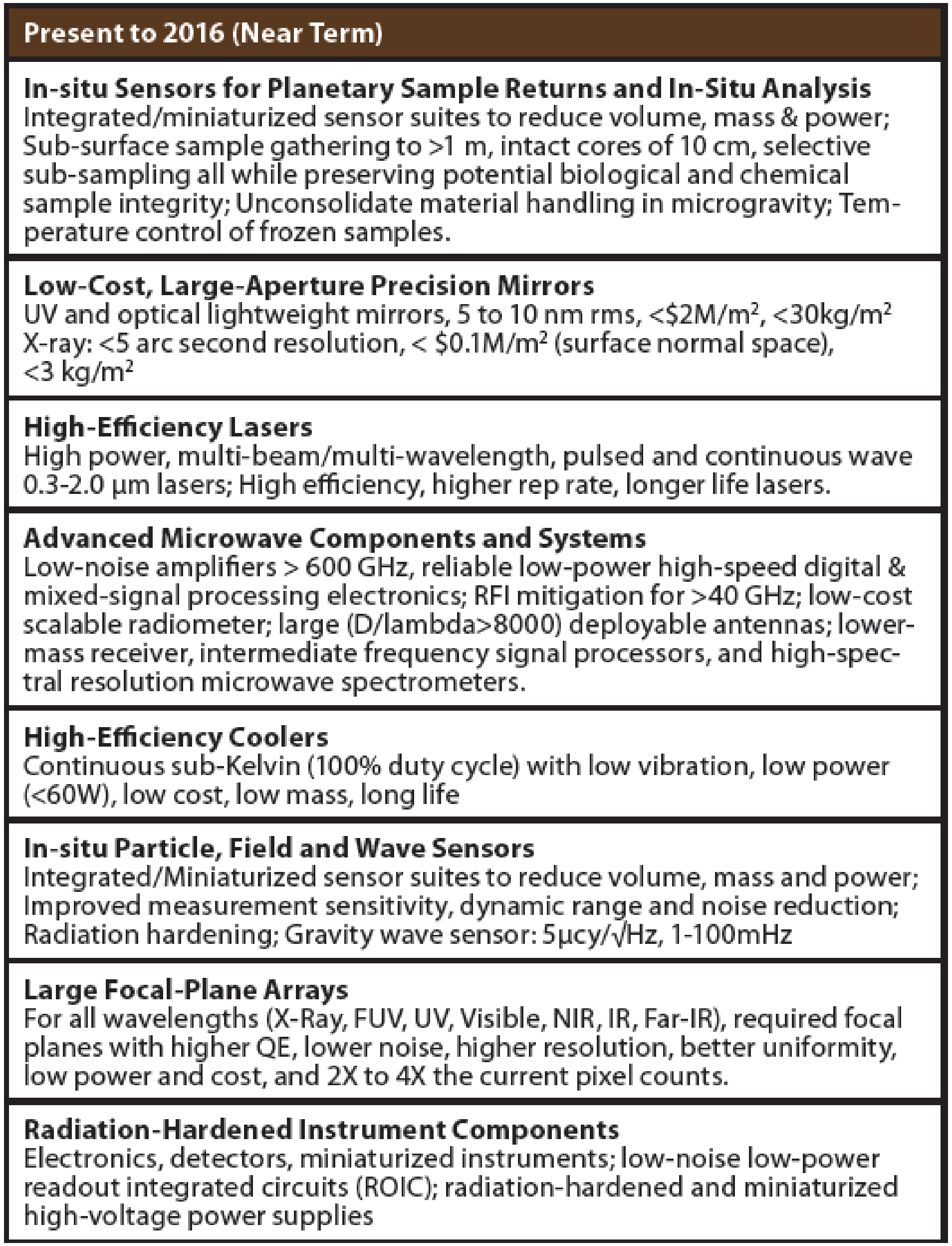
Personal Concern 4

We must question the impression that US industry, even if not well supported now, “will be there when we need it”.

→While our Prime Contractors and Sub Tier Contractors may appear diverse and financially robust, we must recognize that the sector of each that addresses Space Technology is a profit center.

→ If a profit center does not yield to a growth plan, it will not be continued

→ If there is not enough work to support both NASA centers and Industry, failing to provide a share to industry may result in loss of the domestic industrial infrastructure, and much increased dependence on international technology



Present to 2016 (Near Term)

In-situ Sensors for Planetary Sample Returns and In-Situ Analysis
Integrated/miniaturized sensor suites to reduce volume, mass & power; Sub-surface sample gathering to >1 m, intact cores of 10 cm, selective sub-sampling all while preserving potential biological and chemical sample integrity; Unconsolidate material handling in microgravity; Temperature control of frozen samples.

Low-Cost, Large-Aperture Precision Mirrors
UV and optical lightweight mirrors, 5 to 10 nm rms, <\$2M/m^2, <30kg/m^2
X-ray: <5 arc second resolution, < \$0.1M/m^2 (surface normal space), <3 kg/m^2

High-Efficiency Lasers
High power, multi-beam/multi-wavelength, pulsed and continuous wave 0.3-2.0 µm lasers; High efficiency, higher rep rate, longer life lasers.

Advanced Microwave Components and Systems
Low-noise amplifiers > 600 GHz, reliable low-power high-speed digital & mixed-signal processing electronics; RFI mitigation for >40 GHz; low-cost scalable radiometer; large (D/lambda>8000) deployable antennas; lower-mass receiver, intermediate frequency signal processors, and high-spectral resolution microwave spectrometers.

High-Efficiency Coolers
Continuous sub-Kelvin (100% duty cycle) with low vibration, low power (<60W), low cost, low mass, long life

In-situ Particle, Field and Wave Sensors
Integrated/Miniaturized sensor suites to reduce volume, mass and power; Improved measurement sensitivity, dynamic range and noise reduction; Radiation hardening; Gravity wave sensor: 5µcy/√Hz, 1-100mHz

Large Focal-Plane Arrays
For all wavelengths (X-Ray, FUV, UV, Visible, NIR, IR, Far-IR), required focal planes with higher QE, lower noise, higher resolution, better uniformity, low power and cost, and 2X to 4X the current pixel counts.

Radiation-Hardened Instrument Components
Electronics, detectors, miniaturized instruments; low-noise low-power readout integrated circuits (ROIC); radiation-hardened and miniaturized high-voltage power supplies

2017 to 2022 (Mid Term)

High-Contrast Exoplanet Technologies
High-contrast nulling and coronagraphy (1×10^{-10}, broadband); occulters (30 to 100 meters, < 0.1 mm rms)

Ultra-Stable Large Aperture UV/O Telescopes
> 50 m^2 aperture, < 10 nm rms surface, < 1 mas pointing, < 15 nm rms stability, < \$2M/m^2

Atomic Interferometers
Order-of-magnitude improvement in gravity-sensing sensitivity and bandwidths
Science and navigation applications

2023 and Beyond (Long Term)

Sample Handling and Extreme Environment Technologies
Robust, environmentally tolerant robotics, electronics, optics for gathering and processing samples in vacuum, microgravity, radioactive, high or low temperature, high pressure, caustic or corrosive, etc. environments.

Spectrometers for Mineralogy
Integrated/miniaturized planetary spectrometers to reduce volume, mass and power.

Advanced Spatial Interferometric Imaging
Wide field imaging & nulling to spectroscopically image an Earth-twin with >32x32 pixels at 20 parsecs.

Many Spacecraft in Formation
Alignment & positioning of 20 to 50 spacecraft distributed over 10s (to 1000s) of kilometers to nanometer precision with milli-arc second pointing knowledge and stability

Particle and Field Detectors
Order-of-magnitude increase in sensitivity

What are the top technical challenges for Observatories

- Having NASA Centers and Industry ready in a climate of limited funding
- Aperture
- Coatings
- Dimensional Stability
- Sensors (density, noise, full well, spectral coverage)
- Data downlink

What are Observatory technology gaps that the roadmap did not cover?

- Resources to evaluate competing technology
- Continuity
    - It is harder to fund a concept as it trends toward being a flyable technology
- How to achieve the TRL needed for flight
- “Test what you fly and fly what you test”? A process for qualifying systems that cannot be tested on the ground
- Increasing role of actuation as systems get larger and less rigid

What are some of the high priority technology areas that NASA should pursue?

- Mirror fabrication technology
- Mirror active figure control technology

Do the high priority areas align well with the NASA's expertise, capabilities, facilities and the nature of the NASA's role in developing the specified technology?

- Reasonably so
- Are we pushing lightweight forms too the extent that mirrors are too sensitive to thermal perturbation and too difficult to test on the ground?

Do the high priority areas align well with the NASA's expertise, capabilities, facilities and the nature of the NASA's role in developing the specified technology?

- Yes

How well is NASA's proposed technology development effort competitively placed?

- Significant offshore capability is emerging. NASA needs to focus both NASA Lab work and industrial funding toward results

What specific technology can we call a "Game Changing Technology"?

- Adaptable mirrors that can be changed either at the pupil or at a reimaged pupil, using data from phase diversity or other methods.

Is there a technology component near the tipping point?

- Optical substrate fabrication and optical finishing techniques break classical paradigms for mass and performance
- Parallel capacity making segmented mirrors viable

What is the time horizon for the technology to be ready for insertion (5-30 years)?

- Various lengths depending on
  - Starting TRL
  - Clarity of technical goal
  - Ability of NASA to rapidly down-select most promising technologies
  - Continuity of appropriate level of funding
  - Clarity of ground rules of how flight worthy TRL will be achieved
- Too slow a process induces “forgetting”, and brightest people do not engage here
- Usually
  - innovation follows funding,
  - sustained technology development follows a break-through development

Provide a sense of value in terms of payoffs, risk, technical barriers and chance of success

- Expect success
- But we must remove barriers, keep our best people developing technology, rather than an evasive quest of seeking and maintaining funding continuity
  - The duty cycle of technology to proposing for technical dollars must be increased.
  - Clear requirements, gates and funding continuity

Personal Concern Overview

PC1: Planning and continuity issues

PC2: Decline of resources to support both NASA centers and Industry as we know it

PC3: Current levels of Protectivism is limiting US participation in the international growth market.

PC4: Will the US industrial element be carried forth sufficiently

Consequences:

→ As we have less work, technical "forgetting" (loss of art) is inevitable

→ Our best and brightest scientists will spend most of their time competing over and over again for the little work there is

→ Mentoring will diminish. Talented technical people will not enter the field

→ Joint missions with ESA or JAXA may favor industrial work in those countries, further leading to the industrial demise in our country

Summary

- Breakthroughs in both technology and science, as well as funding will morph the technology plan as presented
- NASA Observatory technical success may depend more on the vision of how technology is managed and funded, and recognition we are entering Space 2.0, than specific technologies seen now
- NASA technology plan is sound viewed from today

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and
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