APD Pause and Learn Update – HabEx Study

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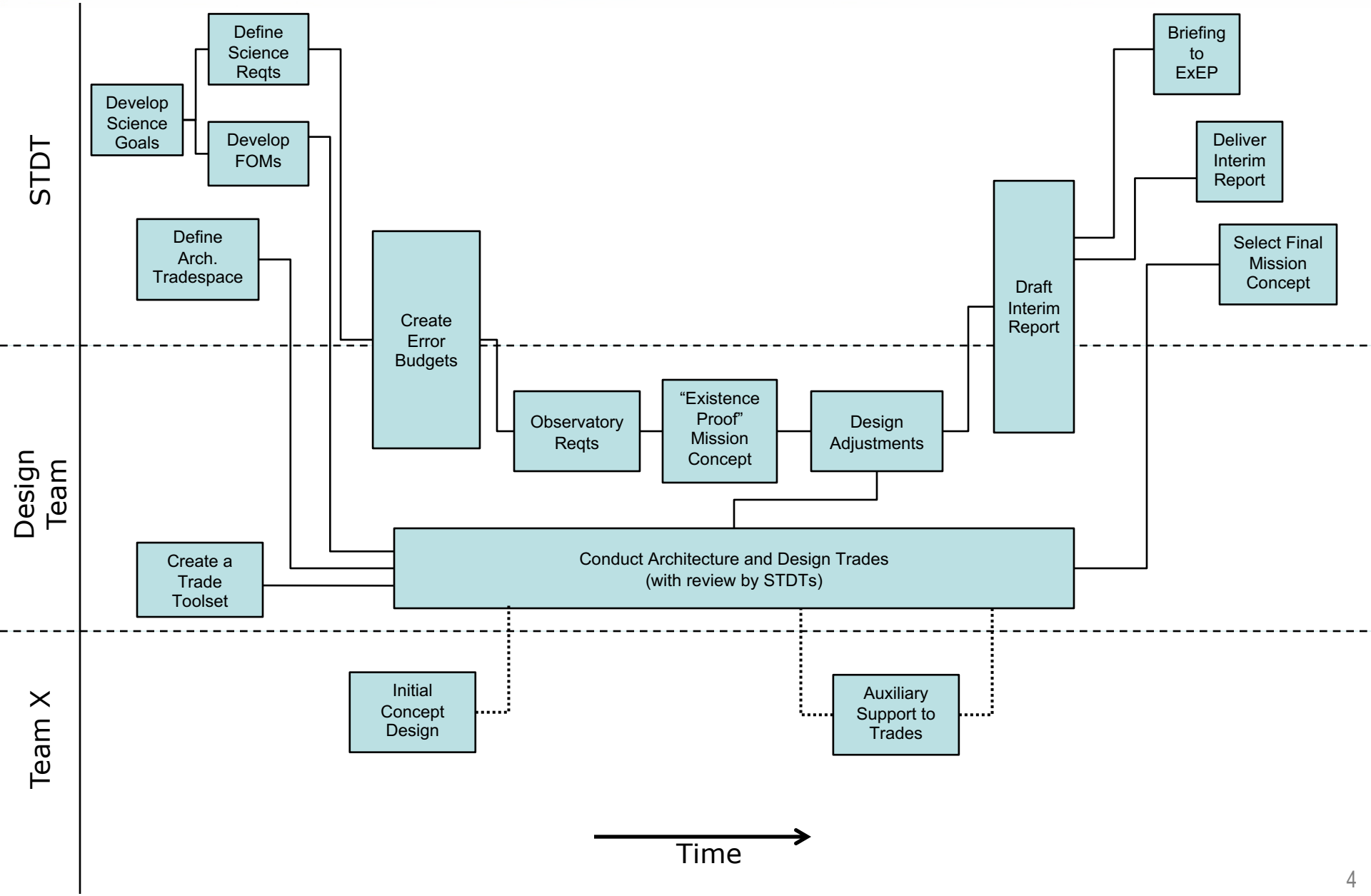
CURRENT STATUS ON STUDY PROGRESS AND APPROACH

HabEx Status

- Settled primary science figure of merit
- Completed rough cost estimation and yield calculation methods
- Settled telescope aperture question
- Determined the general astrophysics instrument candidates
- Completing 4m telescope sizing and rough layout
- Completing first-cut designs on the two general astrophysics instruments
- Started overall flight system architecture trade
- Started starshade sizing trades
- Started technology evaluations for likely candidate architectures

Notional Process to Interim Deliveries



HabEx Work Process (1/2)

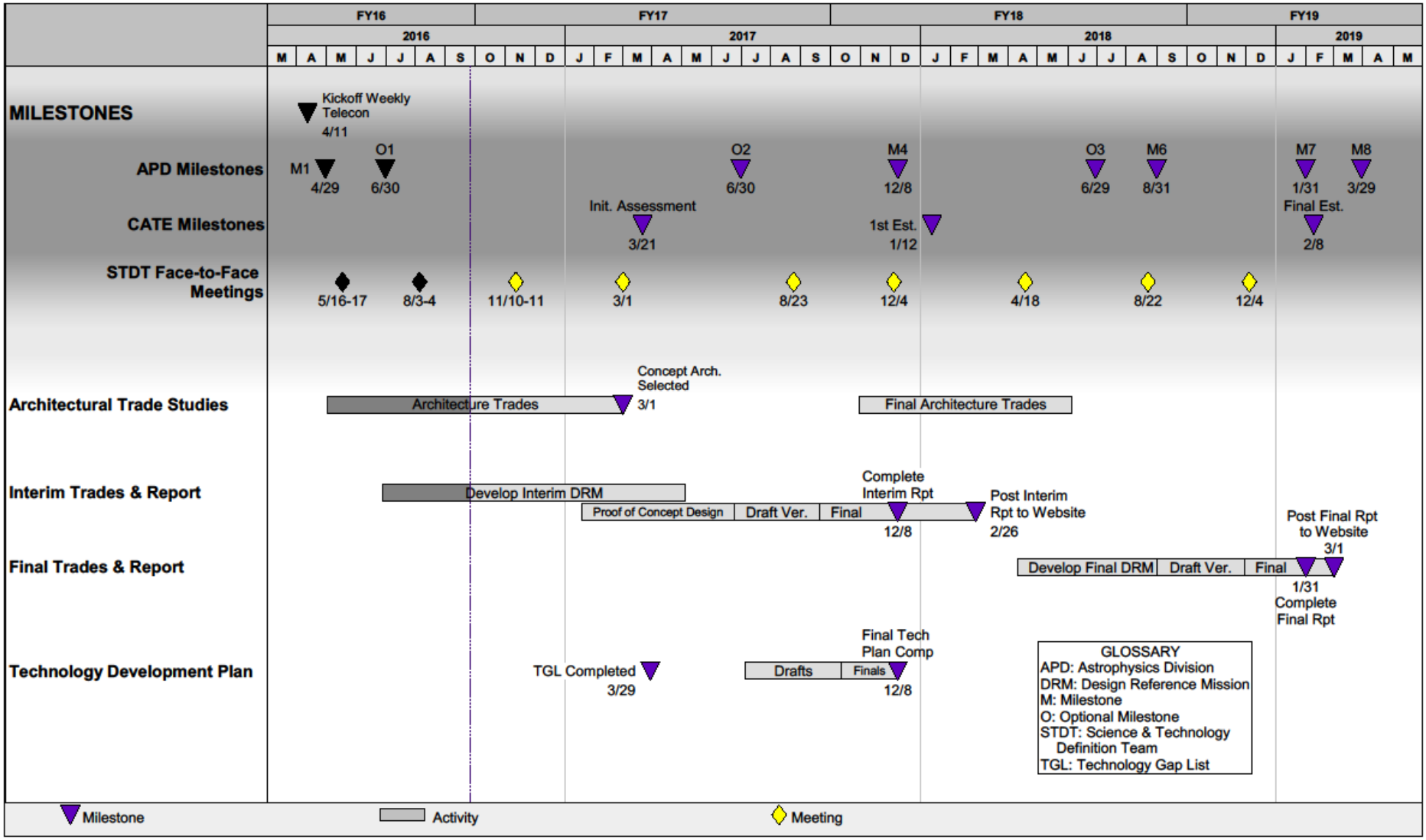
- Early work conducted by the STDT to set science goals, necessary trades and high-level design requirements
  - STDT has simplified and also complicated the work
    - STDT has removed the telescope aperture trade by settling on a 4m monolith and a 6.5m segmented designs…
      - …but the STDT now requires two concepts as study products
    - The STDT has also simplified the general astrophysics (GA) instrument trade by reducing six possible concepts down to two based on a discussion on relative science value
- Early Design Team work focused on a review of the current state-of-the-art of key technologies
  - Detectors, mirror coatings, mirror materials, laser metrology, wave front control
- HabEx will do the 4m then the 6.5m
  - Each will undergo architecture trades then drill-down on one design
  - GA instruments are a side trade
  - Coronagraphs are a side trade and will be completed after the interim report
- Design Team work is now proceeding in three areas:
  - 1) The primary focus is in setting the flight system architecture
    - Working now to define the options to trade and the trade criteria
    - Establishing the cost, risk and performance of each option at a high level
    - Will settle the architecture in February/March

HabEx Work Process (2/2)

- Design Team work is now proceeding in three areas (cont'd):
  - 2) Working on the preliminary telescope design
    - Trading F# and coatings vs polarization
    - Evaluating mirror materials
    - Some risk of the need to redo the telescope design depending on the outcome of the architecture trade
  - 3) Also starting work on starshade trades
    - Capturing any required starshade technology developments on the 2019 timeframe
    - Trading IWA against starshade size and bandwidth
    - Work will feed into the flight system architecture
- Future work before the interim report
  - Team X will design the GA instruments this month
  - Finish out the 4m design in spring/summer of 2017
    - GA instruments and most of the telescope design work will be completed before the spring of 2017
    - Team X will design the telescope and possibly starshade busses
    - Need to work out details on vibration isolation, thermal shielding, launch vehicle packaging, trajectory design, and update the formation flying design
  - Rough-out the 6.5m architecture for the interim report
    - Likely will not have a detailed design ready for the interim report…
    - …but will have a rough idea of the science, cost, risk and probably mass

HabEx: Habitable Exoplanet Imaging Mission Study

9/25/16



HabEx Work Organization

- JPL Design Team
  - Membership is currently heavy in optical, starshade and instrument design
  - Adding members as we develop a need
  - Will be adding thermal, mechanical, flight system systems engineering, configuration, pointing control and formation flying expertise
- MSFC Participates on the Design Team
  - Providing Telescope SE, thermal and mechanical engineering
  - Also providing SLS expertise
- NGAS also Participates on the Design Team
  - Working on starshade-related architecture trades
- STScI is providing science yield estimates
- Future Additional Industry Participation
  - We may need additional industry support for 6.5m design
  - Will add where we cannot find the needed expertise in house

Architecture Trades

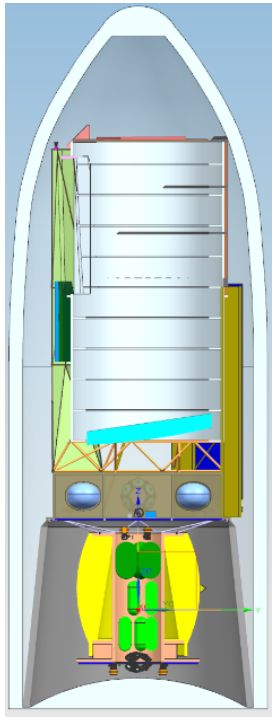
- 5 architectures (so far) being evaluated for 4m design
  - Using Kepner-Tregoe evaluation process
  - Will repeat for 6.5m when we reach that design
- Develop high-level tools to evaluate performance, cost and risk
  - Using Stark's yield analysis performance, ghosting the CATE method for cost, counting new technologies for risk.

TRADE STATEMENT: Recommend a 4m exoplanet direct detection architecture for HabEx study concept development

Description			Architecture Trades				
			1	2	3	4	5
			Starshade Only	Corongraph Only	S & C	2 Starshades	S & 10^{-9}C
Evaluation	***MUSTS***						
	Technical						
	M1	Can search the HZ of XX nearby stars					
	M2	Can spectrally characterize planets from 400nm -1000nm					
	M3	Can spectrally characterize planets to >RXX resolution					
	M4	Operational for 5 years or more					
	Schedule						
	M5	Ready for KDP-A by 2025					
	Cost						
	M6	Total estimated cost will be less than $XXB					
	WANTS (DISCRIMINATORS)	***Weights***					
	Technical						
	W1	Spectrally characterize to XXnm in IR					
	W2	Spectrally characterize to XXnm in UV					
	W3	Minimize number of new technologies					
	W4	Maximize characterization of all planet types					
	W5	Maximize characterization of HZs					
	Schedule						
	W6	Reach TRL 5 at earliest possible date					
	Cost						
	W7	Minimize cost					
Risk Evaluation	***RISKS***						
	R1						
	R2						
	R3						
	OPPORTUNITIES						
	O1						
	O2						

Team X HabEx Studies

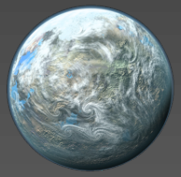
- Mission study to set spacecraft design
  - Study will be just after the 4m architecture is set
    - Will run a second study for the 6.5m architecture
  - Concurrent team will be used to do bus and mission designs only
    - Telescope, starshade and coronagraph will be developed by the Design Team
  - Changes to the telescope, starshade and coronagraph likely to impact the bus will be rippled through the Team X design by a Team X systems engineer after the study.
- General Astrophysics (GA) instruments
  - Team X will design a UV spectrograph and a GA camera this month
  - Most likely one will be selected for inclusion in the flight system design
  - No additional GA instrument design work for 4m
    - Proof-of-concept…not system optimization
    - May revisit selection for 6.5m but will want to reuse as much as possible from the 4m GA instruments
      - …due to time and money



Common Areas Between HabEx and other Studies

- LUVOIR
  - Regular HabEx/LUVOIR management call each month
  - Share three STDT members with a fourth as *ex officio* on LUVOIR
  - Sharing information on common technologies
    - LUVOIR made available a series of tech notes from earlier studies
    - HabEx shared results of recent polarization simulation
  - Using the same exoplanet yield estimator
  - Discussing a reconciliation of cost and technology for later in the study
  - Exo-Science
    - Will have a common description of ground/space capability at launch
    - Will have common exoplanet parameter definitions and valuations
- OST
  - Initial discussions on exoplanet science in the mid/far IR between chairs
- X-ray Surveyor
  - One shared STDT member

Difference between LUVOIR and HabEx?



- Both LUVOIR and HabEx have two primary science goals
  - Habitable exoplanets & biosignatures
  - Broad range of general astrophysics
- The two architectures will be driven by difference in focus
  - For LUVOIR, both goals are on equal footing. LUVOIR will be a general purpose "great observatory", a successor to HST and JWST in the ~ 8 – 16 m class
  - HabEx will be optimized for exoplanet imaging, but also enable a range of general astrophysics. It is a more focused mission in the ~ 4 – 8 m class
- Similar exoplanet goals, differing in quantitative levels of ambition
  - HabEx will *explore* the nearest stars to "search for" signs of habitability & biosignatures via direct detection of reflected light
  - LUVOIR will *survey* more stars to "constrain the frequency" of habitability & biosignatures and produce a statistically meaningful sample of exoEarths
- The two studies will provide a continuum of options for a range of futures

EXTERNAL COMMUNITY INVOLVEMENT

HabEx External Community Involvement (1/2)

- Industry Engagement
  - Working with NGAS on the starshade related trades
  - Will engage industry SMEs where expertise is needed
    - Telescope fabrication expertise, deployable optics and vibration isolation are possible areas
  - Will not engage industry as an outreach exercise
    - Industry needs to bring unique and valuable expertise to the study, and must make study designs and analyses available to the public
    - Industry engagement costs money, complicates study logistics and can slow concept development, so there needs to be value in their participation
- Scientific Community
  - Presentations at various scientific conferences, focusing on the most well attended and/or most relevant.
    - Examples: SPIE*, AIAA, ExoPAG 14, AGU, ExoPAG 15, AAS 229 Special Session
  - Web site: http://www.jpl.nasa.gov/habex/
    - Overview of science and technology, team members, relevant documents and reference materials (including starshade and coronagraph videos, TEDx talks), and news and events
  - No formal process for feedback from the community, but our telecons and meetings are open and well advertised.

*http://adsabs.harvard.edu/abs/2016SPIE.9904E..0LM

HabEx External Community Involvement (2/2)

- Public Engagement
  - Have a public engagement lead in place (Alina Kiessling, JPL)
  - HabEx website – plan to include additional publically-accessible overviews of the mission, science, technology
  - HabEx has been included in ~8 online news articles, including: Space.com, Scientific American, Tech Times, Space Policy Online, Air & Space
  - Google hangout
- International Participation
  - Four observers:
    - Christian Marois – CSA
    - David Mouillet – CNES
    - Timo Prusti – ESA
    - Andreas Quirrenbach - DLR

LESSONS LEARNED & MOVING FORWARD

Lessons Learned (1/4):

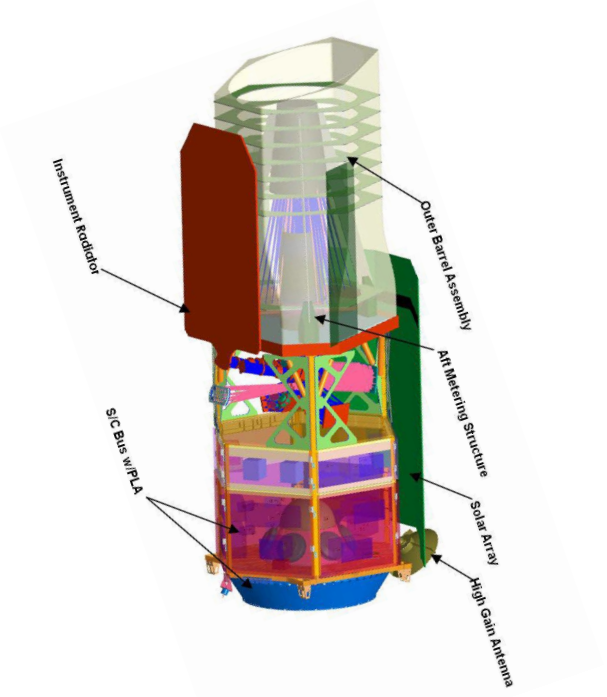
- Start with the science
  - Work the science goals without tying to implementation (architecture, technologies, instruments)
  - Gives a clearer understanding of the science musts and wants
  - Lets the science drive the implementation
- Weekly telecons between the Chairs and the Center Scientist and Study Manager are of real value
  - Keeps close coordination between STDT and Study Team activities
  - Cadence keeps the work moving along
- Develop a management plan for the STDT activities early
  - Members are very busy volunteers so clear tasks with deadlines are needed to keep the team focused and the work moving along
- Be proactive in engaging with the other STDTs as appropriate
  - Interaction with LUVOIR has been positive and useful
  - Will help with consistent science assessment and messaging to the community
  - May have more value if we identify redundancies and avoid duplication of effort
  - Chairs are best positioned to drive this engagement

Lessons Learned (2/4):

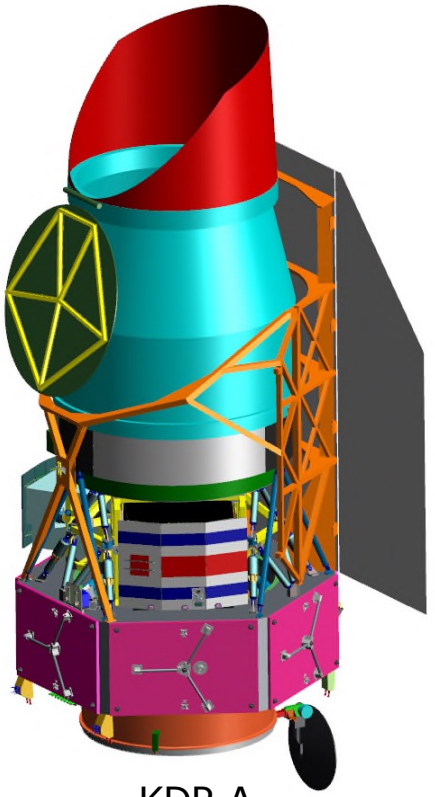
- Use early rough estimates of performance and cost to narrow the architecture tradespace.
  - Early tradespace information helped build STDT buy-in/consensus around a two telescope sizes
- Drill down on only 1 or 2 architectures (1 is better)
  - Funding and time limitations
- Need early architecture tools or methods for determining cost, risk and performance.
  - Tools must work with minimal information
- Establish constraints on cost, risk and performance early
  - Helps limit the trade space that needs to be evaluated
  - Constraints need to be tied to a plan for a successful study result
- Consider KT approach to build consensus

Lessons Learned (3/4):

- Do not optimize…the study output is just a proof of concept
  - Any future mission may have instrument AOs, may decide other features competitively and may take advantage of technological advances or programmatic opportunities



2010 Decadal Survey
1.5m JDEM Omega



KDP-A
2.4m WFIRST

Lessons Learned (4/4):

- Use the concurrent engineering teams for non-critical design work, and do not duplicate in the design team.
  - We use a Team X SE to modify the original Team X estimates for design team changes that ripple through the flight system
- Use industry where they add value
- Get a CATE (or CATE-like) assessment of the interim design
  - Ghost the CATE cost method to assess your architecture options and design
  - CATE red risk rating can prevent prioritization
- New Technology = Risk
  - Too many new technologies is a request for technology development funding, not a new mission.
  - Use the tools you have. Do not chase the technology.
- Study products should be focused on Decadal Survey needs
  - What does the committee need to see to determine the scientific importance of the concept?
  - What detail does the CATE need to determine the cost and the risks associated with the concept?

Barriers Encountered and Overcome (or not)

- ExoSIM yield tool development
  - The ExoSIM tool is many months behind schedule and posed a threat to completion of HabEx architecture trades
  - Worked an agreement with Chris Stark (STScI) to support HabEx in addition to LUVOIR with yield estimation
- International participation
  - Have not yet optimized foreign participation
    - Would like to find a place in the concept development for foreign involvement

- **Is there something that HQ or the PO can provide? Processes/rqmts/deliverables that might be reduced or streamlined?**
  - Get the Standards Team operational
  - Clarify CATE support, particularly for the interim report
  - Identify useable L/Vs within the likely launch dates of the concepts
  - Identify NASA communications capability in the 2035 timeframe
  - Clarify the pass through funding process
    - For travel and other Center support
- **Do you have any issues or concerns at this time that may impact your final deliverables?**
  - The additional 6.5m option. Can we fit it into the funding and schedule?
- **Do you have any suggestions for NASA to consider that may improve the current process/communication?**
  - No
- **Is there merit in holding a joint technical information meeting with all STDTs to gauge the maturity level per STDT?**
  - We do not see the value

BACK-UP CHARTS

Online Articles Featuring HabEx

- http://www.space.com/31778-nasa-next-great-space-telescope.html
- https://www.scientificamerican.com/article/nasa-considers-its-next-flagship-space-telescope/
- http://www.techtimes.com/articles/129976/20160202/nasa-wants-to-build-a-telescope-that-can-potentially-find-signs-of-life-in-other-planets.htm
- https://www.scientificamerican.com/article/if-there-are-aliens-out-there-where-are-they/
- http://www.spacepolicyonline.com/news/nasa-studying-four-potential-large-astrophysics-missions-for-next-decade
- http://www.airspacemag.com/space/Kepler-Children-180959775/?no-ist
- http://www.geekwire.com/2016/proxima-centauri-b-years/
- http://www.space.com/30429-starshade-alien-life-search-wfirst-tech.html