



# APD Pause and Learn Update – HabEx Study

Keith Warfield

HabEx Study Office Manager

Jet Propulsion Laboratory, California Institute of Technology

June 1, 2017



# **CURRENT STATUS ON STUDY PROGRESS AND APPROACH**

# HabEx Status



- Completed several design trades before the 4m architecture trade
  - Polarization driven contrast vs. telescope F#
  - Coronagraph sensitivity to telescope induced wave front error
  - Starshade sizing vs bandwidth and inner working angle
  - Leveraged the LUVOIR Segmented Coronagraph Design and Analysis Study
  - Instrument sizing, cost and technical risk studies were conducted with Team X
  - Many technology assessments aimed at minimizing low TRL technology usage
- 4m Architecture trade is settled
  - Evaluated 4 architectures: starshade only, coronagraph only, starshade and coronagraph and two starshades
  - Baseline design is an unobscured telescope with a coronagraph and starshade
  - Primary general astrophysics instrument is a UV spectrograph with a wide field “workhorse” camera as a possible second contributed instrument
- Additional work on a 4m segmented on-axis telescope contributed by JPL’s National Security Program Office
  - Telescope will be used in the starshade-only alternative 4m options

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

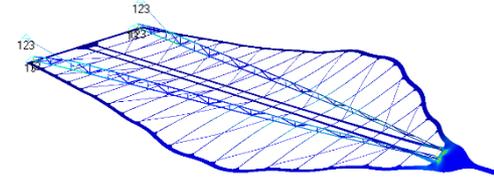
Requirements and Figures of Merit (RMTs, Metrics, Risks and Opportunities)	Assigned Working Group	High	4				5		6		7	
			Large Starshade UV to NIR & Coronagraph (VIA to NIR)	Small (VIA) Starshade & Large Coronagraph (VIA to NIR)	Coronagraph Only (VIA to NIR)	Large Starshade Only (VIA to NIR)	Large Starshade Only (VIA to NIR)	Large Starshade Only (VIA to NIR)				
<b>WANT'S DISCREMINATORS</b>	Grand Total	100	79	69	64	67	62	62	62	62	62	
<b>W01</b> Measure orbits of all detected planets with periods in the mission	A&WG	High	6	10	8	10	10	10	10	10	10	
<b>W02</b> Maximize the number of orbits measured for habitable zone	W02	High	5	10	8	5.8	10	10	10	10		
<b>W03</b> Maximize spectral characterization of all planets	W02	High	5	10	8	8	10	10	10	10		
<b>W04</b> Can operate continuously and measure orbits of any detected ones	W01	High	5	10	8	8	10	10	10	10		
<b>W05</b> Can be delivered in the field of use many stars as possible	W01	High	5	10	8	8	10	10	10	10		
<b>W06</b> Spectrally characterize up to 1000 stars in IR	W01 & 5	Med	4	10	10	10	10	10	10	10		
<b>W07</b> Planet search capability for binary stars	W02 & 5	Med	4	10	10	10	10	10	10	10		
<b>W08</b> Spectrally characterize to 200 nm or below in UV	W01 & 2	Med	2	10	10	10	10	10	10	10		
<b>W09</b> Spectrally characterize as many planets as possible to 200 nm or below in UV	W02	Med	2	10	10	10	10	10	10	10		
<b>W10</b> Spectrally characterize measure limits for all many systems as possible for giant planets and pulsar/star stars for variety of stellar types	Design Team	Med	2	3-4	8	2-3	8	1-2	8	2-3		
<b>W11</b> Maximize the number of stars	W02	Med	2	10	8	8	10	10	10	10		
<b>W12</b> Maximize the number of stars	W02	Med	2	10	8	8	10	10	10	10		
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<b>W100</b> Maximize the number of stars	W02	Med	2	10	8	8	10	10	10	10		

# HabEx Status



- JPL and NGAS Starshade designs have been completed
  - Mechanical and thermal performance analyses are under way with the JPL design
- The telescope and instrument optical layouts have been completed
- Telescope design is well under way
- Team X designs of the starshade and telescope buses are in draft form
- Currently pursuing a telescope bus design without reaction wheels
  - Micro-thruster technology is flight proven
  - Simplifies the design and reduces risk
- RFI responses are in. We will be contacting UTAS and two micro-thruster developers for added expertise to the study.
- Extensive technology TRL discussions with ExEP in advance of the P&L meeting and O2 delivery
- Working to complete instrument designs, micro-thruster/telescope stability modeling, and starshade thermal performance simulations
- Added three new members to STDT:
  - Chris Stark (STScI)
  - John Clarke (BU)
  - Peter Plavchan (Missouri State) [following completion of contract]

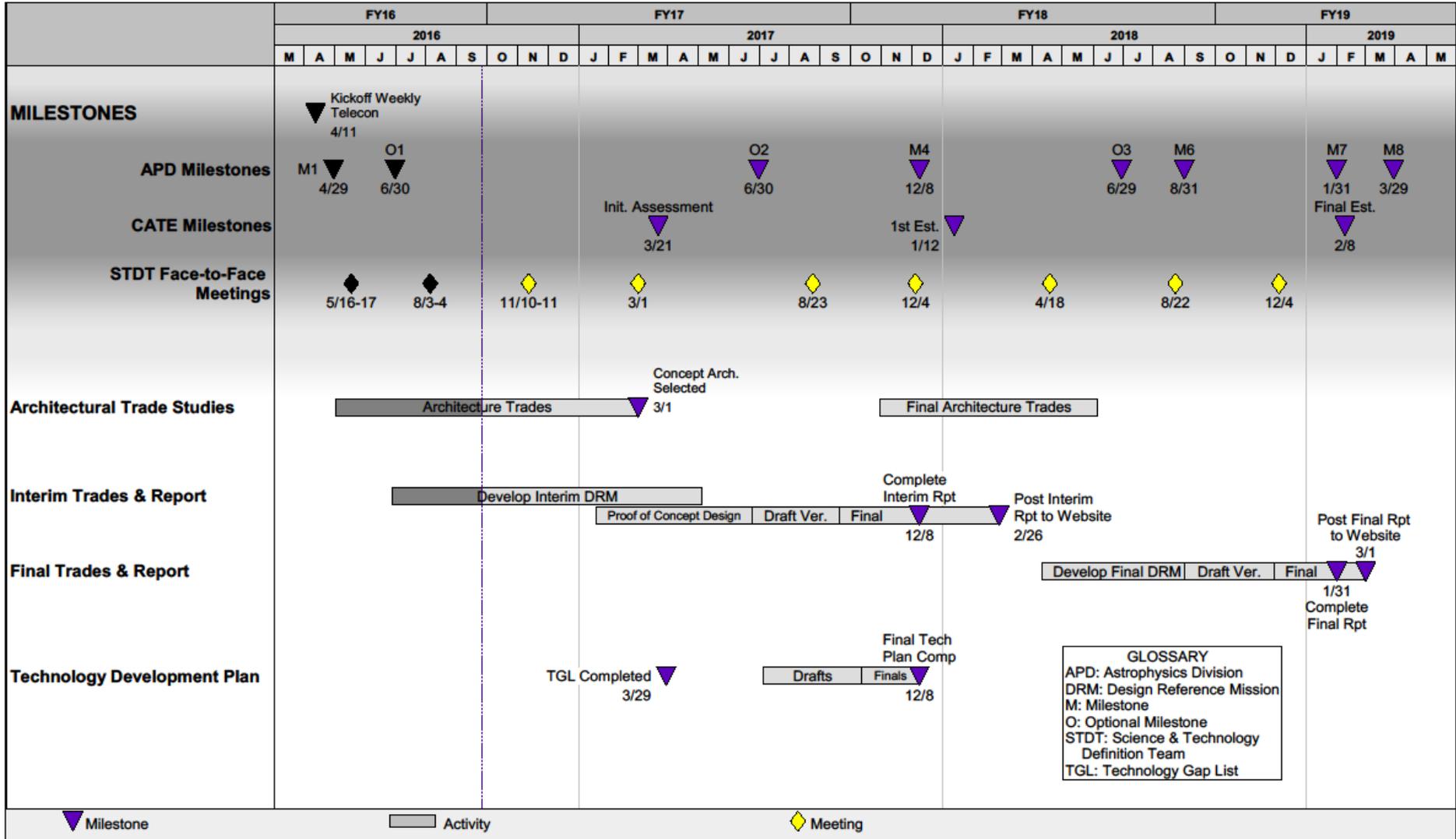
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# HabEx: Habitable Exoplanet Imaging Mission Study

9/25/16



# HabEx Key Activities



- FY17

- CATE critique of the 4m architecture
  - Looking to get feedback on CATE perceived threats to the baseline architecture
- Get telescope and micro-thruster industrial participants on the Design Team
- O2 delivery on the 4m option

- FY18

- Deliver Interim Report
- Discuss Interim Design at AAS
- Deliver Interim CATE inputs
  - We are electing to get a CATE estimate of the interim design to help guide any 4m design adjustments in FY18
- Settle the 6.5m architecture and design
  - Option identification and cost, risk and performance assessments will begin in FY18 with selection in January. Design work will run to July
  - MSFC will oversee the telescope design. Will likely get help from JPL NSPO and GSFC.
  - Starshade may not require much more design work but may we may choose a different design

# HabEx Key Activities



- FY18 (cont'd)
  - Team X study on the 6.5m bus design
    - Another Team X study will be run to design a bus for the 6.5m telescope
  - O3 delivery on the 6.5m option and any update on the 4m option
- FY19
  - Deliver the final report
  - Deliver the final CATE inputs



# Team X Instrument Sizing Studies

- Studies completed in November 2016
- Needed to get an early assessment of the UV Spectrograph and the Wide Field “Workhorse” Camera ahead of the architecture selection
  - Looking for rough mass, cost and technical risks associated with each option
  - Also wanted to identify any requirements the instrument would place on the telescope, flight system or operations
- Mass and Cost were roughly the same
- Chief difference was the need for low TRL coating on the telescope mirrors for the UVS
- HabEx still chose the UVS as the primary General Astrophysics instrument due to higher value science but also did not adopt the low TRL mirror coating
  - UVS is limited to  $> 115\text{nm}$
  - Workhorse Camera is also included in the design as an optional contribution

# Team X 4m HabEx Mission Study



- Initial look at the bus and mission design for the baseline HabEx 4m architecture
  - Study utilized the MSFC telescope design and JPL starshade design
  - Shared SLS launch to L2
  - Coronagraph, starshade camera, UVS and wide field GA camera
  - No reaction wheels on observatory...micro-thrusters instead
  - Starshade 3-axis stabilized
- Results not yet finalized
  - Tight volumetric fit in SLS
  - Mass a little higher than expected but not an issue with SLS
    - Verifying assumptions with Team X
  - Cost came in as expected
- Will do a follow-up study to convert the starshade to spin stabilized

# Common Areas Between HabEx and other Studies



- LUVOIR
  - Monthly telecons between HabEx and LUVOIR leadership teams.
  - Informal but regular communication between Aki and Scott (via phone or email).
  - Joint HabEx/LUVOIR meetings (Nov 16 and Aug 17)
  - Developing a set of slides that address cross-cutting issues between HabEx and LUVOIR (technologies, difference between our approaches, cost, etc).
  - Cross-STDT membership in various science and technology working groups. Coordination of general astrophysics themes that scale with aperture.
  - Regularization of yield estimates between HabEx and LUVOIR (via Chris Stark).
  - Sharing information on common technologies
    - LUVOIR made available a series of tech notes from earlier studies as well as a more recent assessment of segmented aperture coronagraph performance
    - HabEx shared results of polarization simulation
    - Both teams have had extensive discussions on the current state of critical technologies
  - Exo-Science
    - Have common exoplanet parameter definitions and valuations
    - Will have a common description of ground/space capability at launch
- OST
  - Discussions as needed (i.e., offering to help OST with their exoplanet science case and facilitating their interaction with the Standards Team)
- Lynx
  - Discussions as needed (i.e., exchanges with Feyal Ozel and Gary Blackwood about Lynx's exoplanet science applications).
  - One shared STDT member



# EXTERNAL COMMUNITY INVOLVEMENT

# HabEx External Community Involvement (1/2)



- Industry Engagement
  - Working with NGAS on the starshade designs
  - Will engage industry SMEs where expertise is needed
    - Reaching out to UTAS for help with large monolith mirror development
    - Also reaching out to Thales-Alenia and Busek for help with micro-thrusters
- Scientific Community
  - Presentations at various scientific conferences, focusing on the most well attended and/or most relevant.
    - Contribution presentation on STDTs at AAS 230 and handouts for AAS 230
    - Participation in occurrence rate panel discussion at ExoPAG 16
    - Possible talk at AGU 2017
    - Gearing up for a splinter session, handouts, etc., at AAS 231
  - 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



- Public Engagement

- Have a public engagement lead in place (Alina Kiessling, JPL)
- HabEx website – overviews of the mission, science, technology
- Google Hangouts – participated in one earlier, another coming up in September

- International Participation

- Five observers:
  - Christian Marois – CSA
  - David Mouillet – CNES
  - Timo Prusti – ESA
  - Andreas Quirrenbach – DLR
  - Pieter de Visser – SRON (new)



# LESSONS LEARNED & MOVING FORWARD

# Lessons Learned: Communication



- Regular, weekly STDT telecons are essential.
- Weekly leadership telecons are equally, if not more, essential.
- Having one community chair regularly attend the design team meetings enables a strong connection between the STDT and design team, which facilitated the flow of information and aided in making informed design choices.

# Lessons Learned: Decision Making



- Small working groups with strong leads are a productive way of focusing effort into answering specific questions, developing science cases, and exploring technology requirements
- The K-T matrix methodology was very useful for highlighting objective differences between different architectures and getting STDT buy-in on one specific architecture
- The K-T matrix methodology, combined with the working group products, was very helpful in building intuition about how survey strategy, science yield, risk, cost, and complexity play against the specific architecture trades.
- Limiting the Tradespace is a process
  - Trade constraints must not only be justified but their science consequences must also be understood
  - Technology risks require time to assess and to socialize
    - Effort is needed to gain acceptance inside and outside of the STDT
    - It takes time get the STDT to recognize and accept only enabling technologies

# Barriers Encountered and Overcome (or not)



- Technology assessment negotiations with ExEP
  - We found some significant disagreements with older HabEx technology assessments carried by ExEP
    - Earlier assessments were not tied to the HabEx design so the presumed performance requirements did not align with our view of the problem
    - Many design decisions had been made to reduce requirements on key technologies
  - Significant effort was needed to describe our design and our assessment of the technological challenge to the ExEP technologists ahead of O2
  - But through the effort we solidify our own understanding of our technology position and will be able to make a stronger case for our position in the report
- Re-plan
  - The STDT wished two cover two designs instead of one in the report
  - We needed to re-plan
    - Looking to get help on the 6.5m design from GSFC and JPL NSPO
    - Will reuse design elements where possible
    - Cannot support very much 4m post-interim report work



- **Is there something that HQ or the PO can provide?  
Processes/rqmts/deliverables that might be reduced or streamlined?**
  - How can we get the draft interim reports reviewed by PO and APD as fast as possible? What can be done to streamline the review process?
- **Do you have any issues or concerns at this time that may impact your final deliverables?**
  - No
- **Do you have any suggestions for NASA to consider that may improve the current process/communication?**
  - No