HabEx Architecture and Instruments

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Architecture – Initial Round

- Aperture trade
  - STDT selected 4m unobscured and 6.5m on-axis telescope designs for study
  - Decision based partly on an assessment of science per dollar, partly on an assessment current industry mirror capabilities, and JWST leverage value
- GA instrument trade
  - STDT general astrophysics members identified 6 high-value instruments for evaluation by the whole STDT
  - Discussions within the STDT reduced the instruments for evaluation to two: UV spectrograph and a UV/VIS/NIR camera
  - Both instruments sent to Team X for rough design
    - Team X identified new technologies, liens generated on the flight system and operations, and cost for both candidates
  - STDT will select the best option for integration into the concept design
- L2 assumed as the orbit
  - Earth trailing/leading limits life and starshades must co-launch
  - Earth orbits are unattractive due to thermal and field-of-regard considerations
  - L2 orbit size remains a small trade. Presently assuming a WFIRST-like orbit.

Architecture – Second Phase

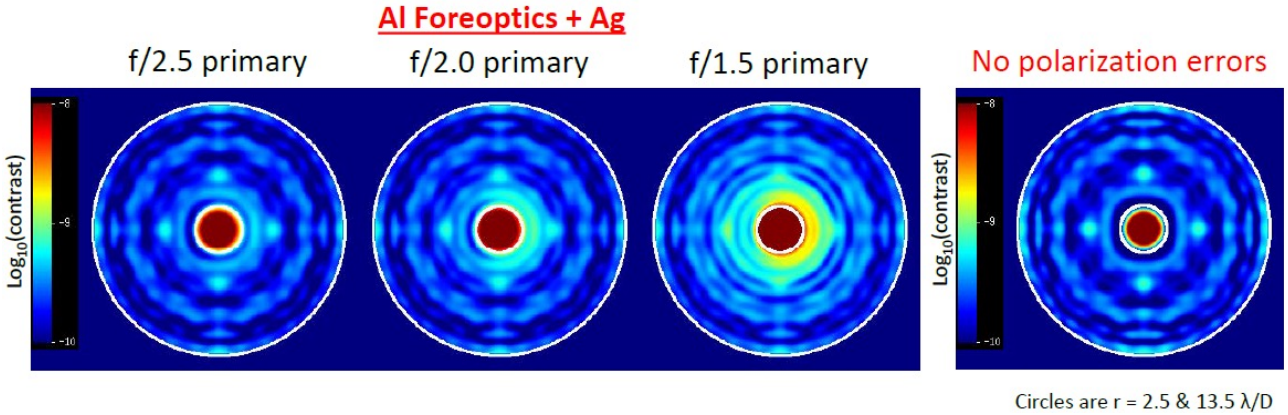
- 5 unique architectures (so far) being evaluated for 4m design
  - Additional variations based on extended bandpass (both in the blue and the red)
  - Will repeat for 6.5m when we reach that design
- Using high-level assessments for performance, cost and risk
  - Using Stark's yield analysis (performance), ghosting the CATE (cost), counting new technologies (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						

Telescope Trades

- Telescope is unobscured if the coronagraph is in the architecture
- F#
  - Early polarization simulations indicate that F#s less than 2 showing significant contrast degradation
  - 2.5 meeting contrast performance with Exo-C Lyot and Vector Vortex charge 6 coronagraph designs
  - Slower telescopes not desirable due to mass, cost, volume
- Mirror Coatings
  - Hubble-like Al out performed Ag for coronagraph polarization/contrast
  - Newer UV coatings need to be evaluated for polarization
- Mirror Material
  - Early look at materials favored Zerodur due to extended low-CTE temperature range.
  - Additional data on ULE provided by L. Feinberg. Will be evaluated before a final recommendation.



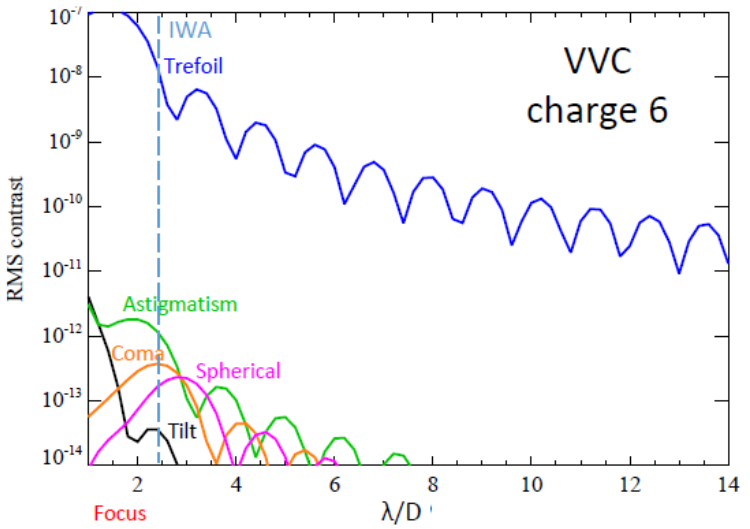
Graphic from presentation by J. Krist and S. Martin, *Impact of Polarization Aberrations, including Cross-Polarization Terms, on the HabEx Coronagraph*, October 26, 2016

Starshade Trades

- Size
  - Currently working starshade sizing which is a function of bandpass and IWA
  - Starshade must fit in 5m fairing to allow second (or follow-on) launches
  - Minimizing dry mass will extend the delta-V and improve yield
- Deployment Method
  - Will also evaluate NGAS and JPL deployment methods for use in the 4m and 6.5m concepts
    - Overall concept cost and technical readiness will be the criteria

Coronagraph

- Early simulations with a Vector Vortex charge 6 looks promising
  - Less sensitive to wave front error than other coronagraph architectures
  - Contrast < 10^{-10} from IWA (2.4 λ/D) to OWA for F# 2.5 and 2.0 telescopes
    - 4m unobscured telescope design with HST-like aluminum coating



- Plan for other performance simulations
  - Will develop and evaluate HLC and PIAA designs optimized for the 4m
  - Results of the current assessment of coronagraphs for segmented telescopes will guide the study team in 6.5m telescope coronagraph choices
- Decision on placeholder then final coronagraph
  - Current study plan assumes a placeholder coronagraph for the interim report
  - Final decision on the coronagraph is planned for after the interim report
  - Decision will likely be based on a trade of expected performance vs. risk

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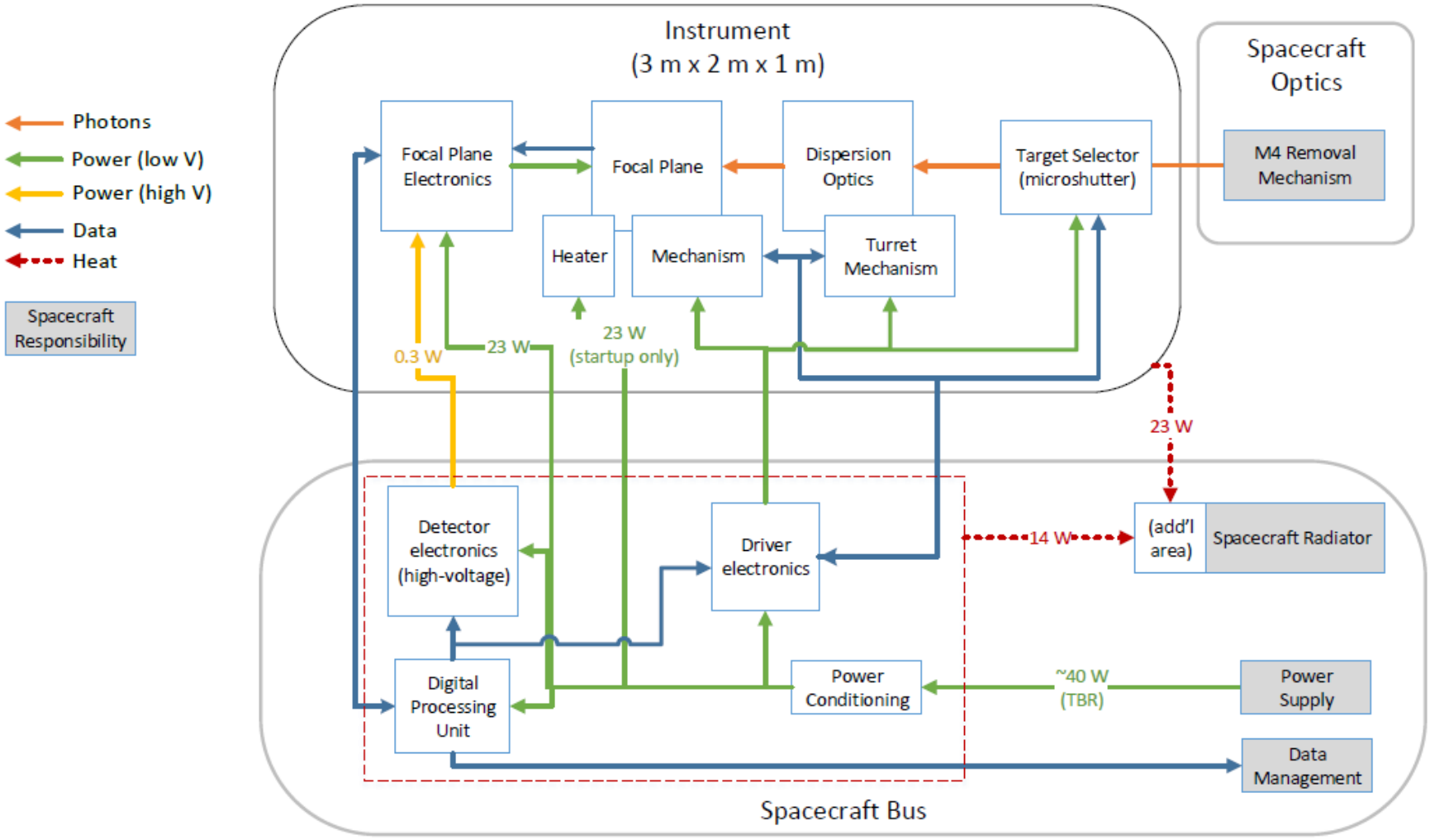
Team X Results – UV Spectrograph



Team X – UV/Vis/NIR Camera

- Block diagram for the dual-beam Low Resolution Imaging Spectrometer (LRIS) on the Keck telescope.
- LRIS has blue and red channels, split by a dichroic, with an optional slitmask placed early in the light path.
- HabEx Workhorse Camera would be similar. Rather than a slitmask, micro-shutter array (as per NIRSPEC on JWST).