Level 1 Requirements Discussion

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Purpose

- AFTA-WFIRST Science Definition Team report (April 2013) identified high level objectives for AFTA-WFIRST DRM and a set of requirements for each science program.
  - Original SDT charter asked what science can you do with the 2.4m telescope responsive to the science priorities for WFIRST.
- HQ has agreed that the science is compelling and we should continue pre-formulation activities for a wide field infrared survey telescope mission using the 2.4m telescope
- As we continue defining this mission, we need to start at the highest level and define what are the key Science Questions, Objectives and Requirements that will drive AFTA-WFIRST .
- Goal over the next ~12 months is to develop a consistent and validated set of requirements, starting at Level 1 and flowing down to Survey, Data Set and key Mission design and ops requirements (i.e. requirements for Spacecraft, Telescope, Instrument, and Ground System elements)

Progress to Date

- Initial meeting held in November with a few SDT members to discuss Level 1 requirements and get initial drafts for discussion among SDT, Study Office and NASA HQ
  - Initial inputs from David Weinberg (DE), Scott Gaudi (microlensing) and Bruce Macintosh & Tom Greene (coronagraphy)
- Initial draft of Level 1s (along with top Science Questions and Objectives) distributed in early December prior to the last SDT telecon.
  - All requirements assumed a notional time allocation for establishing the requirements flowdown and assessing the performance, explicitly called out in requirements.
  - DE requirements had some astrophysical assumptions embedded in the requirements while the microlensing requirements called out explicit assumptions in the requirement.
- Received comments from a couple of SDT members as well Study Office and NASA HQ personnel.

Concerns

- Both Project and HQ comments were along similar lines
  - Remove time allocations and place them at a lower level in an observing strategy section
  - Level one requirements should be written as on orbit performance capabilities that are under the project’s control to implement. We want to avoid writing requirements that depend on astrophysical uncertainties.
  - Requirements should be verifiable.
  - Remember that the requirements are a contract between the Project and HQ and once they are baselined they are extremely difficult to change.
  - We want to keep the number of Level 1 requirements for each science program to a minimum.

Discussion

- What are we missing if we just specify high level sensitivity requirements at Level 1?

Other Level 1 Items

- Do we want any Science Objectives and Level 1 requirements for the NIR sky survey or is it simply a byproduct of the baseline surveys?
- GO requirement of 25% of the total mission time
  - Adding the 6th year to the baseline requires some of that year to be allocated to the GO program and not fully dedicated to the coronagraph. I believe the agreement at the last SDT telecon was to keep it at 25% with the assumption that the “6th year” would be coronagraph time (but split between baseline and GO time). This does not imply coronagraph doesn’t operate until the 6th year.
- Clarification from last telecon, the coronagraph should have Level 1 requirements, but those requirements shouldn’t drive the design requirements for the mission.

Draft Level 1 Requirements as Provided by SDT in December 2013

Dark Energy

Science Questions

- Is cosmic acceleration caused by a new energy component or by the breakdown of General Relativity on cosmological scales?
- If the cause is a new energy component, is its energy density constant in space and time, or has it evolved over the history of the universe?

Primary Science Objective

- Measure the expansion history of the Universe and the history of the growth of matter clustering with sub-percent precision over the redshift range z = 0-2, in order to test possible explanations of its accelerating expansion including dark energy and modifications of Einstein's gravity.

Science Requirements

- Measure the distance-redshift relation over the range of z = 0 – 1.7 using Type Ia supernova with aggregate statistical precision of 0.2% or better, measurement-related systematic uncertainties below 0.2%, and internal cross-checks at the 0.4% level.
- Measure the distance-redshift relation over the range z = 1 – 2 using baryon acoustic oscillations (BAO) with aggregate statistical precision of 0.4% or better and measurement-related systematic uncertainties below 0.2%.
- Measure the amplitude of matter clustering at z = 0 – 2 via weak lensing cosmic shear and the mass function of galaxy clusters, with aggregate statistical precision of 0.2% or better and internal cross-checks at the 0.4% level. Systematic uncertainties associated with weak lensing shape measurements must be controlled at the < 0.1% level, so that they would remain subdominant to statistical errors even in an extended survey over a 4x larger area.
- Measure structure growth via redshift-space distortions in the BAO survey, keeping observational systematic errors below statistical errors.

Exoplanet - Microlensing

Science Questions

- How do planetary systems form and evolve?
- What is the frequency of habitable worlds and what determines their habitability?
- What kinds of unexpected systems inhabit the cold, outer regions of planetary systems?

Primary Science Objective

- Complete the statistical census of planetary systems in the Galaxy, from the outer habitable zone to free floating planets, including analogs of all of the planets in our Solar System with the mass of Mars or greater.

Secondary Science Objectives

- Measure the mass function and projected separation distribution of cold exoplanets with masses greater than that of the Earth and separations greater than 1 AU.
- Measure the frequency, mass, and separation distribution of outer habitable zone planets.
- Measure the frequency of Mars mass embryos
- Measure the frequency and mass function of free-floating planets with mass down to that of the Earth.
- Measure the frequency of analogs of our solar systems with outer gas and ice giants.

Science Requirements

- Detect at least 1500 bound planets in the mass range 0.1- 10,000 Earth masses, including 150 planets with mass <3 Earth masses, assuming a Cassan et al. mass function saturated at 2 planets/dex for planets between 0.3 - 30 AU.

  or
- Detect at least 150 Earth-mass planets assuming every star hosts an Earth-mass planet at 2AU.

- Capability to detect bound planets down to 0.1 Earth masses.
- Detect at least 20 free-floating Earth-mass planets, if there is one per star in the Galaxy.
- Ability to measure masses of at least XX% of the planet host stars to a precision of at least 20%.

Exoplanet - Direct Imaging

Science Questions

- What are the compositions and natures of a variety of planets around nearby stars?
- Which nearby stars have dusty disks, what are the disk properties, and how do disks and planets interact?
- What nearby planetary systems might harbor Earth-like planets that can be studied with more powerful future telescopes?

Science Objective Summary

- Discover new planets and disks around nearby stars. Characterize these new and previously known planets and disks.

Detailed Science Objectives

- Search for giant and smaller planets and low surface density circumstellar disks around at least 100 nearby stars having a variety of spectral types.
- Measure the brightnesses, colors, and visible spectra of newly discovered and currently known planets to characterize the chemical compositions and physical properties of their atmospheres.
- Measure the positions of all imaged planets and combine this information with other Doppler or astrometric data to characterize their orbits.
- Measure the location, surface density and extent of dust in circumstellar regions of nearby stars from (or near) habitable zones to beyond ice lines to understand delivery of materials to inner solar systems. Identify nearby stars having zodiacal dust levels indicating that they may be good or poor candidates for future terrestrial planet imaging.
- Detect and measure substructures within dusty circumstellar debris to understand the parent bodies and the influences of seen and unseen planets.
- Image bright debris disks that are either unresolved by other observatories (e.g., Spitzer, WISE) or resolved but occulted by large coronagraphic masks (e.g., HST).

Level 1 Science Requirements

- Conduct high-contrast imaging of nearby stars over a spectral range of at least 430 – 950 nm with 4 or more filters having bandpasses of at least 10%.
- Conduct a survey with a total search depth of 30 for ice and gas giant planets (4–13 Earth radii and albedo = 0.4) when imaging at 550 nm wavelength with one visit per star.
- Achieve a total search depth greater than 1 for a survey of small (less than 4 Earth radii) planets when imaging at 550 nm wavelength with 1 or more visits per star.
- Be capable of spectroscopically characterizing at least 3 known radial velocity planets assuming a red planetary albedo of 0.2. These observations shall consist of R > 50 spectra over at least 600 – 850 nm with SNR > 10 and can be spread over the full 5 year mission.
- Be capable of detecting (SNR=5) a disk of 100 times our solar system's zodiacal flux in or near the habitable zone (1 – 2 AU) of a solar-type star at a distance of 8 pc. This sensitivity is required at 450 and 800 nm wavelengths.*
- Detect and image the inner and middle regions of bright debris disks that have been discovered or studied by Hubble, WISE, or other observatories but not yet spatially resolved or studied in visible light at ~5 – 100 AU distances from their host stars. Moderate contrast imaging to ~100 AU (3 arcseconds) radius is required for these large, bright disks.**

NOTES:

- * This sensitivity is not unique, but the wavelengths are. These data will provide very important information on grain sizes and albedos when combined with LBT-I data.
- ** This may appear to be a new requirement, but it is not. I have written it to justify the 3 arcsec imaging field of view (at lower contrast) that is in Requirement #1 from Bruce's AFTA planet science requirements dated October 24, 2013.
- In order to keep options open, I have not included any requirements for the nearby stars to be surveyed for planets and disks. I also deleted the survey completion times from requirements #2 (6 months) and #3 (2 months) to keep these high-level requirements flexible. I think that the important thing here is that all the required observations fit into the 1 year total time allocated to the exoplanet survey; we can dice up that time more finely at a lower level.