Lessons Learned for ATLAST

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Program Architecture

- Major change in approach to Program Architecture is required
  - ➡ Avoid a single contractor prime where all major sub-systems are subcontracted from prime
    - ➡ loss of control at subsystem is a critical flaw for large flagships
- Government team should be the prime
  - ➡ each major subsystem is a sub-contract managed by government prime
  - ➡ each major sub-system is awarded to most capable contractor
  - ➡ Build the hardware don't develop it: Do not work with technology development houses unfamiliar with the demands of flight hardware. Note that this can be as subtle as which division within a large company
- Issue Call for Proposals for the design you will actually build
  - ➡ Know when you are ready: requires realism up front
  - ➡ Descopes are more expensive
- I&T experts (instrument, OTE, SC) should be mandatory at design phase
  - ➡ don't design hardware that is costly, difficult and/or impossible to integrate and test

Program Architecture

- Oversight
  - ➡ JWST PIT should be the model for technical oversight
  - ➡ Every major element should have a PIT
- Robust Margins
  - ➡ Traditional performance margins are insufficient for complex flagship scale missions
  - ➡ In my experience systems-level dependencies erode margin more rapidly than small missions
  - ➡ Protect and defend robust margins at outset: they will gone by launch
- Specify “fly as you test” versus “verification by analysis” philosophy from day 1 and manage expectations
- Consider linking SI science time to cost performance
- Avoid cryo - but if you have to keep it simple

Avoid Over-reaching: Mind the Gap

- Former NRO manager: "only take one major new step at a time"
- Avoid major conflicts in performance requirements that drive-up cost
  - ➡ excessively wide wavelength coverage
  - ➡ wide versus narrow field
  - ➡ detectors requiring cryocoolers (e.g. MKIDs for NIR or visible cameras)
- Do not add capability that has not been fully assessed
  - ➡ avoid compelling but simplistic analysis as arguments for late add-ons !
- Understand your hardware requirements and their cost implications
  - ➡ Not clear that we understand how to specify exoplanet imaging missions
  - ➡ If we get it wrong it will be very expensive to fill the gaps
- Keep it simple and properly assess complexity
  - ➡ with exoplanet imaging simplest designs are often the most complex because they are not "integrated solutions" and exhibit fractal growth
- Large space deployables (starshades) are not "a simple" alternative
  - ➡ they are big, complex and far from fully developed concepts

Instrument Concept

- Common instrument architectures are mandatory

  1. Optical bench & mount materials

  2. Common mechanical, electrical and data interfaces

  3. Provide alignment adjustment in each instrument: Do not drive telescope and I&T costs with complex alignments that could be more easily mitigated at SI level

  4. Avoid dual-role instruments:

     - Don;t embed engineering functions in science instruments e.g. WFSC should be accomplished with a dedicated instrument unless closed loop control with a coronagraph is required

  5. Avoid refractive optical systems

- Partners have to agree to instruments terms in order to participate

Technology

- Invest early in technology
  - ➡ JWST mirror development is a perfect model
  - ➡ No technology is TRL-6 until it has been reviewed for the mission requirements.
  - ➡ Ignore “we have done this before arguments”. Demand proof!
  - ➡ Start using active structures: Excelis is excellent example
- For flagship missions complexity is >> sum of the technologies
  - ➡ Missing TRL-6 technology is always the System Engineering
    - ➡ Numerous new technologies have to work together in harmony
  - ➡ Integrated modeling capabilities are way behind the curve
    - ➡ Proposal assessment should include integrated modeling capabilities including available computing facilities
    - ➡ Make this known to Contractors now: Current state of the art is unacceptable so include a real analysis test case in site visit
  - ➡ Carefully assess interface technologies
    - ➡ e.g. articulated arms may have to carry harnesses

Requirements

- Requirements have to be more clearly written
  - ➡ if you wanted zodi-limited performance state the wavelength range *and what you define as zodi-limited*
- Image quality should be in terms of wavefront error and encircled energy at specific radii. Strehl ratios should be avoided
- Start out with a clear set of definitions for ACS (pointing) and define their linkage to image quality prior to developing error budgets
- Start with the error budgets you mean to live with and use them in the Call for Proposals with mandatory templates
  - ➡ have a clear policy on MUFs at the start of design
- Do not finesse performance predictions with unrealistic assumptions e.g. cleanliness requirements ..... they will get descoped and you will pay
  - ➡ telescopes should not look at 2Pi-Sky (use a tube)
- Identify clear examples of the live or die science case needed for each science requirement

Requirements

- **Exoplanet Imaging**
  - ➡ **requires a new paradigm in requirements definition**
  - ➡ **extremely robust margins are mandatory since performance degradation is not gentle**
  - ➡ **extreme complexity in contrast, IWA and pointing requirements together with their inter-dependencies has to be clearly understood in order to be communicated clearly to engineering teams.**

- **Data Volume**
  - ➡ **its time to compress data and perform onboard image stacking**
  - ➡ **new paradigms for how to do this need to developed**
  - ➡ **start with the data analysts and LSST**