Large Ultraviolet Optical Infrared (LUVOIR) Surveyor Mission Concept Study for the 2020 Decadal Survey

Study Office & Team

LUVOIR Study Manager
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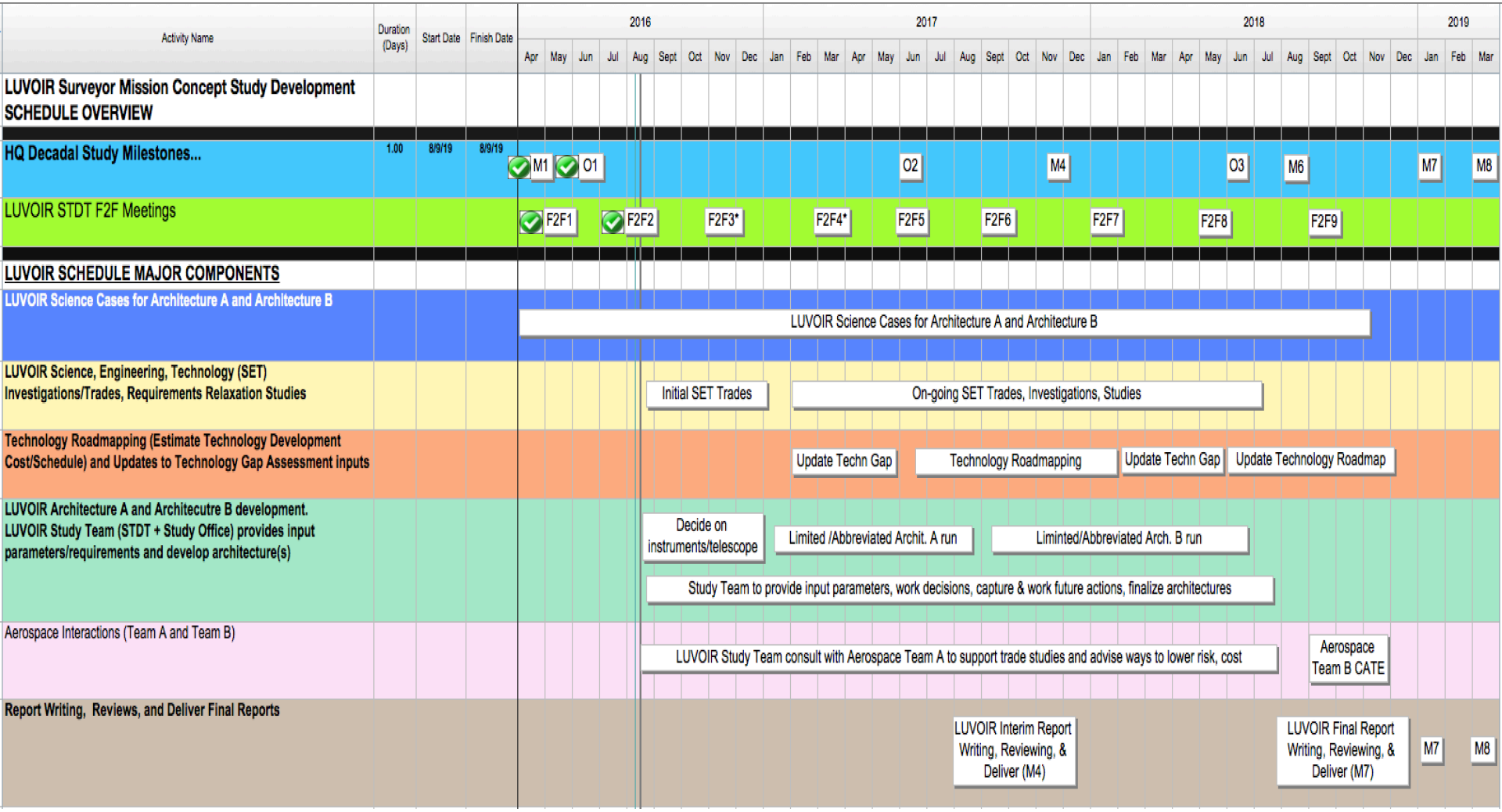
August 18, 2016

Study Success Criteria

Deliver to Decadal a scientifically compelling, technically executable mission concept study that is feasible with respect to technical, cost, and risk resources

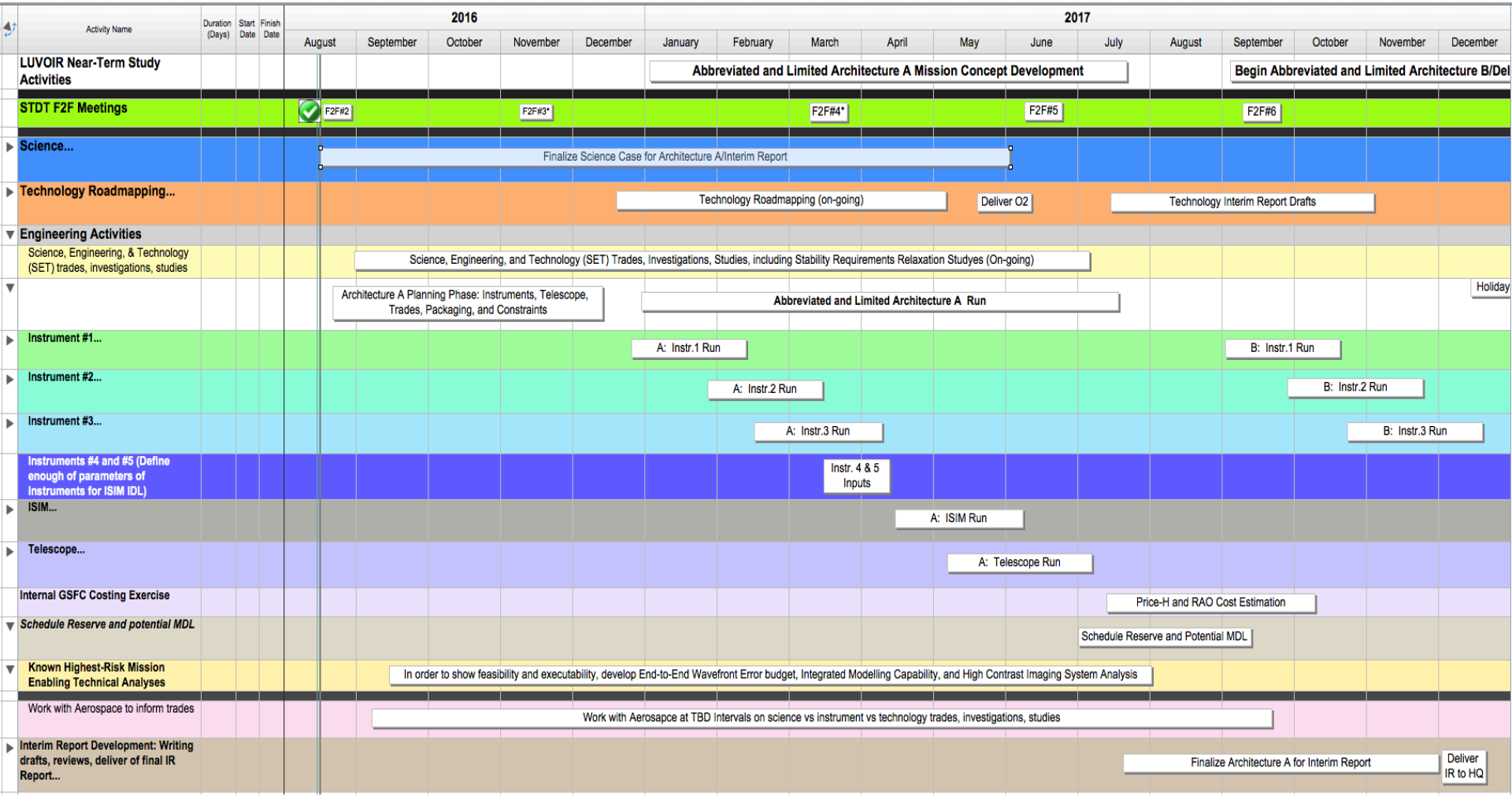
- Present implementation strategies as “reference missions” – credible hardware configurations that can achieve the science goals and are sufficiently defined for a reasonable cost evaluation
- Consider “mission cost vs. science capability”
- Consider the sweet spot factoring in science, technology, cost, and risk
- Provide parametric results for key scientific performances
- Develop credible technology roadmaps (describe required technology funding and timeline) that show how TRL5 will be achieved by KDP-B and how TRL6 will be achieved by PDR

LUVOIR Study Schedule Overview



* = Joint F2F meetings with LUVOIR and HabEx

LUVOIR Study Near-Term Schedule (CY17)



* = Joint F2F meetings with LUVOIR and HabEx

Questions the STDT Needs to Answer

- What instruments are needed for the science laid out so far? (decide Aug 2016 F2F)
- What is the instrument prioritization based on science? (Aug 2016 F2F)
- What instrument details still need to be defined? (Aug 2016 F2F)
- What simulation tools need to be developed to decide instrument details? (Aug 2016 F2F)
- Provide input on engineering choices / trades (Aug – Jan 2017)
- Decide telescope apertures A and B, balancing science and perceived cost risk (Nov 2016 F2F)
- Finalize instrument parameters for Architecture A (Jan 2017)

Near-Term Timeline (STDT Actions)

- **August F2F meeting : focus on instruments**
  - Prioritize instruments based on science
  - Start defining instrument parameters
    - More detail on required parameters will be presented at a telecon coming soon.
  - Assign science lead(s) to each prioritized instrument
  - Request instrument optical designs from experts

- **November F2F meeting: focus on telescope options**
  - Define input parameters. Decide on aperture(s), FOV(s), FOR, wavelength range, on-axis vs. off-axis, etc.

Input information required for the Optical Design Lab

1. Number of instruments? (typically this is just one)
2. If known, tell us your thoughts on the design form(s) and reasons for such. (e.g. three-mirror-anastigmat telescope, due to wide field imaging required, etc.
3. **Wavelength range**, or bandpass, and "design to" wavelength (e.g. desire diffraction limited performance at 1 micron).
4. If the instrument is a spectrometer, please include desired spectral resolution.
5. **Aperture** requirement
6. Is this driven by radiometry (i.e. sensitivity), or resolution (i.e. diffraction limited) ?
7. **Field of view** requirement
8. What is the object distance (e.g. infinity for stars, or altitude for ground observing) ?
9. What is your desired **Pixel sampling** on the sky or ground ?
10. Do you have a detector concept in mind? If so, tell us the pixel size and array size.
11. Please also discuss your performance figure of merit related to pixels (e.g. Airy disc FWHM should span two pixels, or spot size < 1/2 pixel diameter, spectral resolution desired to span two pixel width, etc.)
12. If this is a scanning instrument, tell us the full field of regard.
13. **Systems** requirements
14. What do you think is your **strongest engineering driver**: cost, volume, mass, or performance?
15. Are there any optically important **mechanisms** (e.g. scan or steering mirrors, micro-mirror arrays, etc.)?
16. Are there any optical **interfaces** with other instruments? (e.g. exit pupil location, field stop, etc.)
17. Are there any significant **packaging** or mass constraints for this instrument? Special materials (e.g. Beryllium, etc.)?
18. Are there any special considerations or concerns for ground testing or self-calibration components that may influence the optical design? (e.g. well-corrected interfaces between instrument modules).

Back Up

Study Success Criteria from HQ

- **The final study deliverable shall include:**
  - *Science case for the mission*
  - *Mission and observatory performance requirements that deliver these science capabilities*
  - *Design reference mission, including straw-man payload trade studies conducted to arrive at the final mission concept*
  - *Technology assessment:*
    - *Current status, at the time of submittal of the final report*
    - *Roadmap for maturation to both TRL-5 by the start of Phase-A and*
    - *TRL-6 by the mission PDR*
    - *Phased resources needed to achieve the required technology maturity levels by the start of Phase A and by mission PDR*
  - *Cost assessment, major technical, and risk burn-down plans as a function of science capability.*
  - *Top-level schedule for major phases of development including a notional launch date (assuming entering phase-A as a post-WFIRST budget wedge opens) and top schedule risks.*

Aerospace Interaction Objectives

- **Prime objective**
  - Achieve a better understanding of technical, cost-risk trades and the impacts on the large concepts
- **Approach for achieving the prime objective**
  - Allow study teams to understand cost and risk implications of their mission architecture choices
  - Allow study teams to better distinguish between areas for deeper engineering and areas where rules of thumb can suffice
  - Allow Aerospace Corporation to provide independent guidance and suggestions to the study teams for consideration in reducing the technical and cost risk of the engineering elements.
  - Allow Aerospace to better understand mission concepts, technology requirements and technology maturity as the studies progress, without commenting on the science merits and without creating a conflict of interest situation with National Academies
  - The support will be provided in two phases as described in the following charts
- **The cost of this support is provided through the PCOS/COR Program Office and individual study funds will not be used for this support**

Aerospace Tasks:
Phase 1: August 2016 – June 2017

- **Risk and Cost Driver Identification**
  - It is anticipated that each concept team will have a range of technical options to best determine the desired cost or budget target for the desired science goals. Aerospace will attend meetings of the SDT teams to understand key science requirements and potential impact on the concept design.
  - Aerospace will offer periodic assessments, as appropriate, of top technical and programmatic risks and identify key cost drivers.

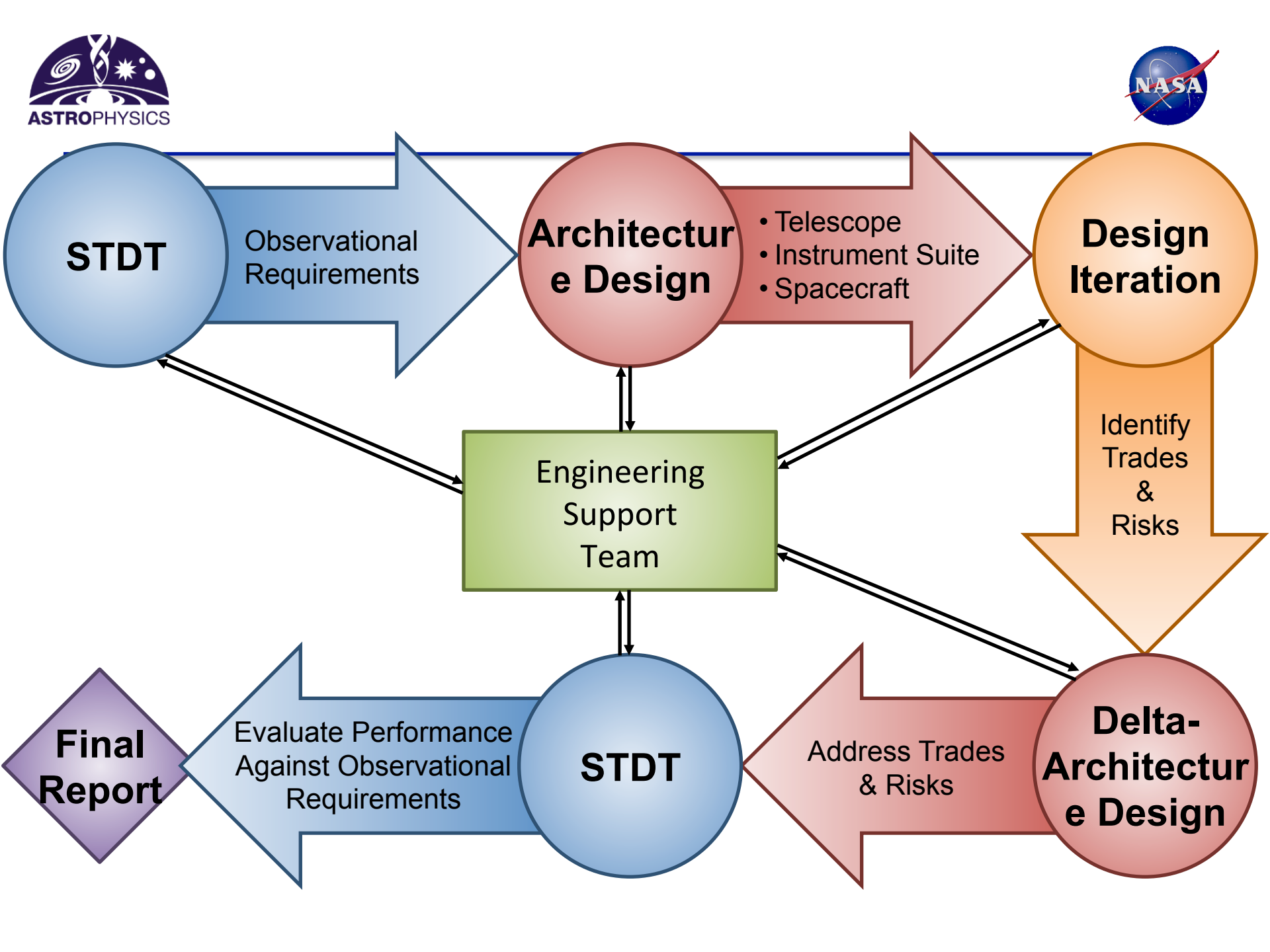
Aerospace Tasks:
Phase 2: June 2017 – Dec 2018

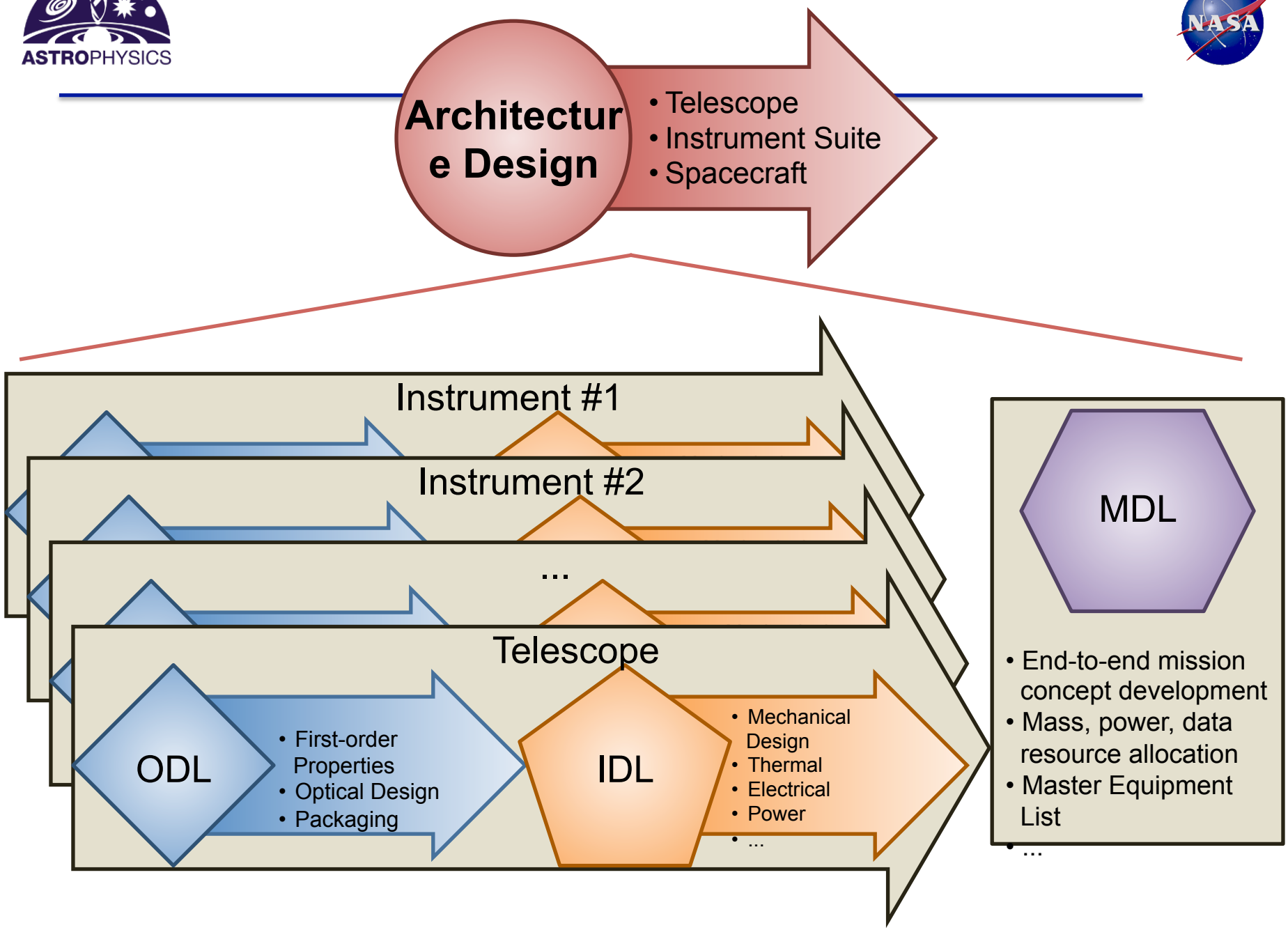
- **Trade Study Support**
  - Focus on trade studies for a baseline concept design
  - Support the tailoring of the CML4 for each study team
  - Offer specialists for more in-depth review at suggested “deep-dive” sessions in top technical risk areas and assist in trade studies to provide focus in development of more mature point designs.
  - Additional deep dive meetings will also be supported where technology must be matured for the mission concept.

Guidelines for Engaging Aerospace

- **Study teams to include designated Aerospace representative on the mailing list for STDT and Engineering team meetings**
- **Study teams may make direct contact with Aerospace to arrange a consultation, as per the scope described on previous pages; contact Debra Emmons, e-mail: debra.l.emmons@aero.org or Zigmond Leszczynski, e-mail: zigmond.v.leszczynski@aero.org**
- **Study teams must inform DSMT (through the Astrophysics Program Scientist) whenever a consultation is arranged with Aerospace**
- **DSMT reserves the right to disallow a consultation if**
  - The consultation purpose is out of scope of Aerospace task
  - The consultation topic will create a conflict of interest situation for Aerospace with National Academies
    - Aerospace is evaluating creation of a separate CATE team firewalled from these NASA commissioned study activities
  - The consultation will exceed the allocated budget for Aerospace task

NASA GSFC's
Integrated Design Center (IDC)
Instrument Design lab (IDL)
Required and/or Desired Inputs


ASTROPHYSICS
NASA
STDT
Observational Requirements
Architecture Design
• Telescope
• Instrument Suite
• Spacecraft
Design Iteration
Identify Trades & Risks
Engineering Support Team
Delta-Architecture Design
Address Trades & Risks
STDT
Evaluate Performance Against Observational Requirements
Final Report


ASTROPHYSICS
NASA
Architectur e Design
• Telescope
• Instrument Suite
• Spacecraft
Instrument #1
Instrument #2
...
Telescope
ODL
• First-order Properties
• Optical Design
• Packaging
IDL
• Mechanical Design
• Thermal
• Electrical
• Power
• ...
MDL
• End-to-end mission concept development
• Mass, power, data resource allocation
• Master Equipment List
• ...

IDL Study Objective

- **NAME of point of contact (POC) for the study, and the alternate**
  - The study POC is the ultimate authority on the technical and programmatic decisions during the study
  - The study POC is also the single person the IDL team will distribute study products to; any further distribution is only done with the permission of the POC (this is true even after the study is complete)
- **One line statement of study objective**
- **Milestones for the IDL team to execute during the performance of the study**
  - trades or decisions about the conceptual design to implement
- **Information or support needed to complete the study**
  - Any prework analysis, input, our guidance from the IDL or IMDC that would influence the approach for your instrument design
- **Date when the study is to be completed**
  - Or when specific products like a mass or cost estimate are needed

IDL Instrument Overview

- NAME of the instrument and the mission it is intended to support
- General class or type of instrument (e.g. spectrometer)
- Previous flight history summary, if any
- Observation desired (field of regard, target, wavelength, resolution)
- Observation dwell time or repetition desired
- Critical instrument technology to achieving the observation
- Recommended or concept for focal plane
- Other focal planes or technologies that should be considered

**Status of Current Instrument Design

If your instrument is immature and the IDL team is largely "starting from scratch", please proceed to the next chart

If your IDL study is based on a current instrument design, we'd like to get as much information as possible (without reading through technical ICDs or long proposals)

Please condense the information down to the specific technical content requested in this prework questionnaire

When possible, please provide the following:

- **Any figures or illustrations available, either hardcopy or electronic**
- **A specific list of changes to be implemented relative to a previously flown or proposed instrument**
- **Mechanical models of the instrument or mechanism you would like us to implement**
  - Or of the spacecraft bus or of any relevant mechanical component
  - In any mechanical drawing software format
- **Any optical models of the instrument, or specific optical components (e.g. a beam expander)**
  - ZEMAX, Code IV, Avatech, FRED, Other _____
- **Any performance models of the instrument, or specific components**
  - e.g. detector QE curves
- **Tall poles in the design that you want the IDL team to modify**
- **Required inputs vary depending on if you are starting with a design or starting from scratch**

Mass Model Input

If your instrument is immature and the IDL team is largely "starting from scratch", please proceed to the next chart

If your IDL study is based on a current instrument design, or a specific instrument approach (i.e. you are asking the IDL to design an instrument based on a design that your provides), please provide us with the following component-level information to initiate our thermal models, and flesh out our mass model of the instrument, which will become the basis for the cost model

Component level descriptions for our mass model, for any specific component you want us to implement in your instrument design:

- **Dimensions**
- **Mass estimate**
- **Materials**
- **TRL**
- **Operating temperature and temperature stability requirements**
- **Power requirements and power dissipation**
- **Survival (non-op) temperature requirements**
- **If the component is available commercially (i.e. it's COTS)**
  - Purchase estimate
  - % composition (e.g. 70% electronics, 30% structure) – this only applies to COTS components
  - % modification/customization (if necessary)
- **Heritage mission references**

Instrument Data Product

- Description of the desired flight data set
- Data array dimensions and refresh frequency
- Estimate of data collection rate
- Description of data format and relation to instrument field of regard

Instrument Application/Mission Summary

- Summary of mission objective
- Relationship of the instrument under study to the mission objective
- Description of the spacecraft orbit, altitude, inclination, etc., and its relationship to the target observation
- Concept of the mission operation and data collection plan

Mechanical Requirements

- **Instrument mass and dimension constraints**
  - Is there a specific launch vehicle fairing identified for this mission?
- **Packaging concept for instrument and supporting electronics**
- **Critical instrument tolerances**
- **Instrument mounting concept and field of view constraints**
- **Spacecraft orientation and pointing stability requirements regarding the observation target or desired data set**
- **Orientation conflicts regarding other spacecraft instruments or field of view intrusions (either fixed or transient)**
- **Special material used: Titanium, Beryllium, Stainless Steel, etc.**
- **Are there any contamination requirements or concerns that affect any of the materials selections?**

Mechanism Assumptions

- **Number and type of mechanisms required**
  - e.g. aperture covers, launch lock, calibration, and focus mechanisms
- **The duty cycle for each mechanism**
  - e.g. continuous during science mode, once per orbit
- **Description of mechanism operation**
  - Number of repetitions per operation, and number of operations per mission
  - The range of motion and required step of motion
  - The precision and knowledge requirements for the step and final position(s)
  - The permitted time to achieve position(s)
- **Any guidance, references, or mechanical models of heritage mechanisms for the IDL to implement in your design**

Optical Requirements

- **Instrument optical design concept – please provide a block diagram if possible**
- **Concept Name (e.g. Ritchey-Chretien,TMA,Offner,Ebert-Faster;etc.)**
- **Please provide any optical models or optical descriptions available, or provide requirements for the following:**
  - Collector area
  - Focal length(s)
  - Plate scale
  - Angular resolution requirements
  - Wavelength Range
  - Spectral resolution and/or dispersion requirements
- **Calibration concept and requirements**
- **Contamination concerns**
- **Stray Light Requirements**
  - Stray light suppression techniques
  - External and Internal stray light sources
  - Optics and Structure: surface finishes and paints
- **Discussion of critical optical features**
- **Special optical requirements such as cooling**

Guidance and Attitude Assumptions

- **Are there any Observing Limitations with respect to the following sources: sun, moon, bright stars, target object, background light, extended sources?**
- **Is image stability required?**
  - Is an active or passive approach anticipated?
  - What is the stability requirement? *(arc seconds over milliseconds)*
- **Is "tracking" of the target required?**
  - What is the required pointing stability during an observation? *(arc seconds over milliseconds)*
- **Is attitude knowledge required?**
  - What is the required accuracy and precision of the knowledge? *(arc seconds over milliseconds)*
- **Are their any assumptions about the exchange of guidance and attitude knowledge between the instrument and the spacecraft?**

Optical Information

- **Reference Documents or URL's.**
- **What level of design and analysis support is needed?**
  - Does an optical design exist?
  - Is conceptual design required?
  - Is tolerance analysis required? (mechanical, thermal?)
  - Is stray light modeling or analysis required?
- **How is optical performance defined or measured?**
  - RMS Spot Size; MTF; Wavefront Error; etc.
- **Any optical models of the instrument, or specific optical components? (e.g. a beam expander)**
  - ZEMAX, Code IV, FRED, Other _____
  - CAD models, STEP, IGES, SAT, or other files
- **Spectral Selection Technique? (filters, gratings, holograms, prisms, etc.)**
- **Material Types? (glasses, mirrors, metals, structural supports, etc.)**

Detector Requirements

- **Type of detector to be used?**
  - Please provide a datasheet and a plot of the detector quantum efficiency (QE), if possible
  - Pixel well depth *(electrons)*
  - Radiation tolerance
  - Estimated integration period (or frame cadence)
  - Digitization resolution *(bits)*
- **Detector operating temperature?**
- **Detector active area and dimensions?**
- **Number of pixels and sequence of pixel readout?**
- **Detector readout rate *(Hz)?***

Electro-Optical Analysis Assumptions

- What is the assumption of the incoming flux?
- What are the band centers for the various instrument channels?
- What are the bandwidths for the various channels, full-width half-max or other measures?
- What is the system entrance aperture?
- What are the detector pixel solid angles in object space?
- What are the throughputs for each of the optics and the total estimated instrument throughput?
- What are the background factors such as detector dark current?
- What are the temperatures of the various optics, walls, windows, etc.?
- What are the noise factors thru the system (read, crosstalk, A/D, thermal, etc.)?
- What are the gain factors?
- What integration times are used for each channel and signal case?
- How many data samples per result? (TDI,etc.)
- What dynamic ranges are used? (bits per channel, etc.)
- Are there any weak, intermediate or strong signal or noise cases to be analyzed?

Thermal Requirements

- **Instrument to spacecraft thermal interface concept**
  - e.g. is the instrument thermally isolated from the spacecraft
- **Passive or active cooling requirements for the instrument and specific components (e.g. detectors)**
  - Please include temperature stability and gradient requirements
- **Instrument radiator field of view requirements or restrictions**
- **Potential thermal impact of solar aspect or Sun intrusion**
- **Instrument structure, focal plane, optics, or Sun shield thermal considerations**

Electrical Requirements

- **Data system interface concept (point to point, data bus, other)**
- **Uncompressed instrument output data rate**
- **Modes of instrument operation including impact on data rate and power requirements**
- **Data storage requirements**
  - e.g. Will data be stored in the instrument or on the spacecraft?
  - What is the anticipated downlink approach (how many minutes per day)?
- **Instrument command and management concept**
- **Power requirements (normal operations, thermal control, other)**
- **Power bus constraints**
- **Emergency instrument power requirements (emergency heaters, actuators, other)**

Flight Software Requirements

- Modes of instrument operation (including impact on data rate and power requirements) such as:
  - Boot / Initialization
  - Standby
  - Diagnostics
  - Keep-Alive
  - Safe
  - Science
- Special safing / commanding requirements
- List science algorithms required for processing science data
- List on-board autonomy required
- List any fine guidance knowledge or computation required
- List any data compression requirements (loss-less or lossy)
- List the time-tag accuracy of the data handling and how you expect to achieve this timing requirement
- List on-board configuration characteristics
- List spacecraft interface complexities

Reliability Requirements

- Instrument Lifetime Requirements? *(years)*
- Instrument Lifetime Goals? *(years)*
- Are their any reliability requirements for this instrument, or subset of instrument channels?
- Are their any redundancy requirements or recommended approaches?
- Is there any reliability data (I.e. life test data, reliability estimates,etc.) for any unique components (I.e. special detectors, lasers, klystroms, etc.) used on this instrument?
- What is the desired/required Probability of Success for the instrument for the required mission? For the goal mission?
- What critical function (or subset of functions) must the instrument be able to perform so that it can be considered in an operating state? What function (or subset of functions), if lost, would constitute a failed state for the instrument? Are there partial failure modes (e.g. loss of non-critical functions) that need to be analyzed?

Primary Trades to be Performed

- **Specific trades requested**
  - List them in order of priority; we may only be able to address one in a 1-week study
- **Technology infusion considerations**
- **Special materials to be reviewed**
  - E.g. documents, websites, previous missions, or previous IDL studies
- **Alternate mission operations concepts to by assessed**
- **Areas of critical margins that may drive instrument design and desired constraint relief**
- **Open areas for alternate instrument architecture and considerations**

Cost Assumptions

- **Mission schedule**
  - Contract award date, PDR, CDR, instrument delivery
- **In-house or out-of-house production**
  - for design, development, I&T, and FSW
  - If it is a contractor, should we assume a medium or large contractor company?
- **Electronics Class (e.g. Class S, Class B, Class B-1, etc.)**
- **Full-up Instrument Production units**
  - Flight unit, engineering test unit (ETU), engineering development unit (EDU), flight spares
- **Sparing philosophy for major assemblies / sub-assemblies/ components**
- **Should we assume a specific Constant Year dollars or Real Year dollars**

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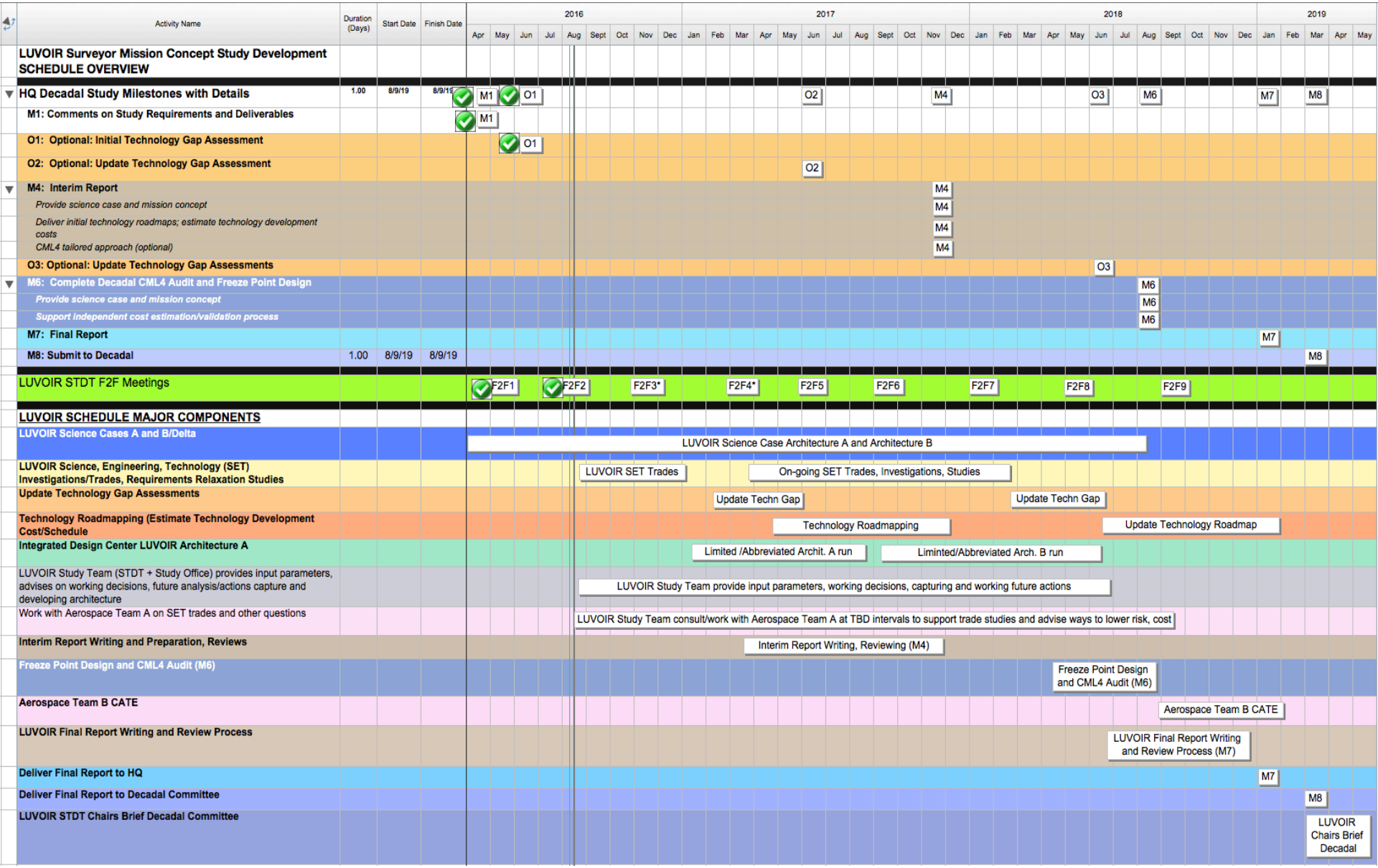
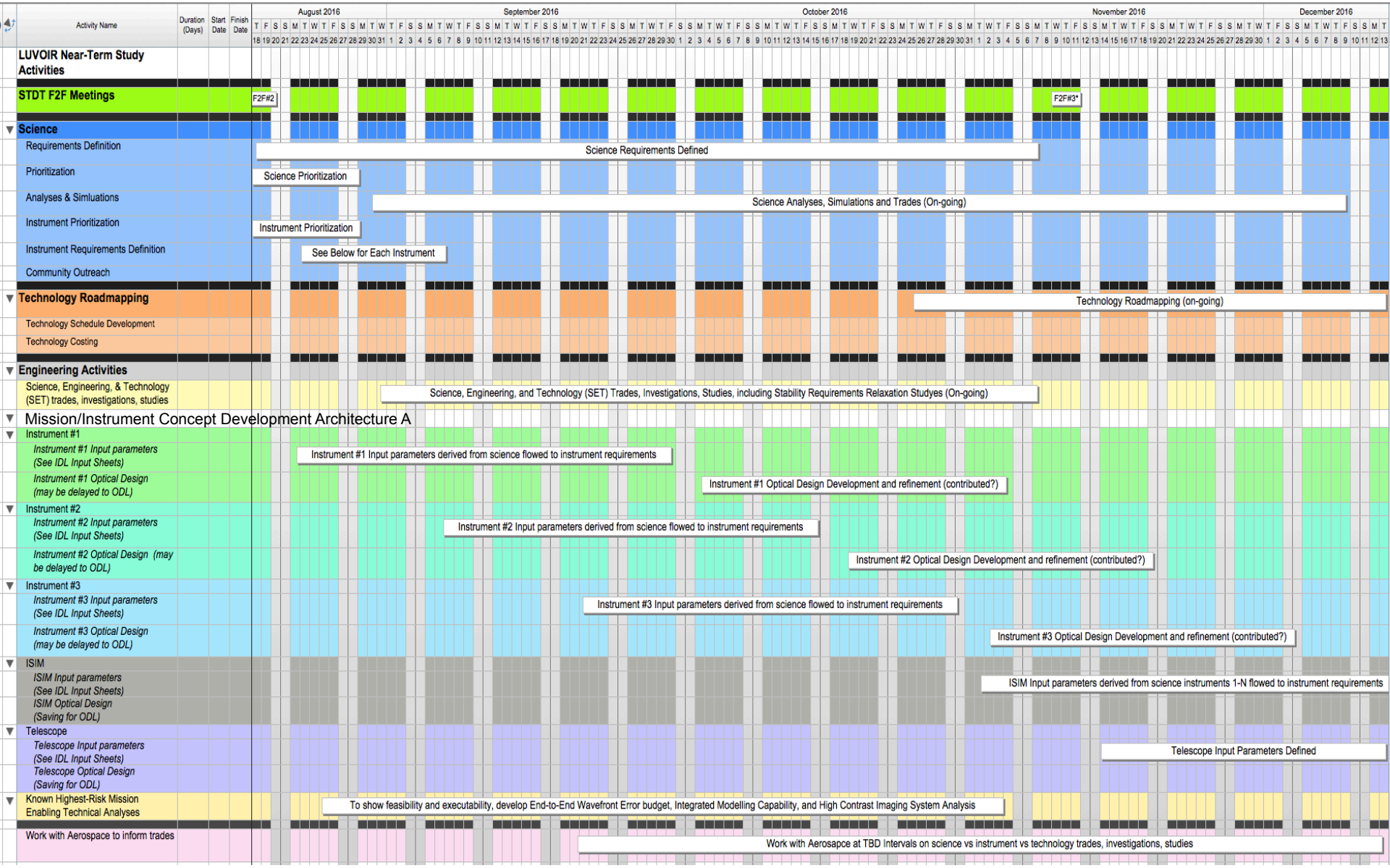
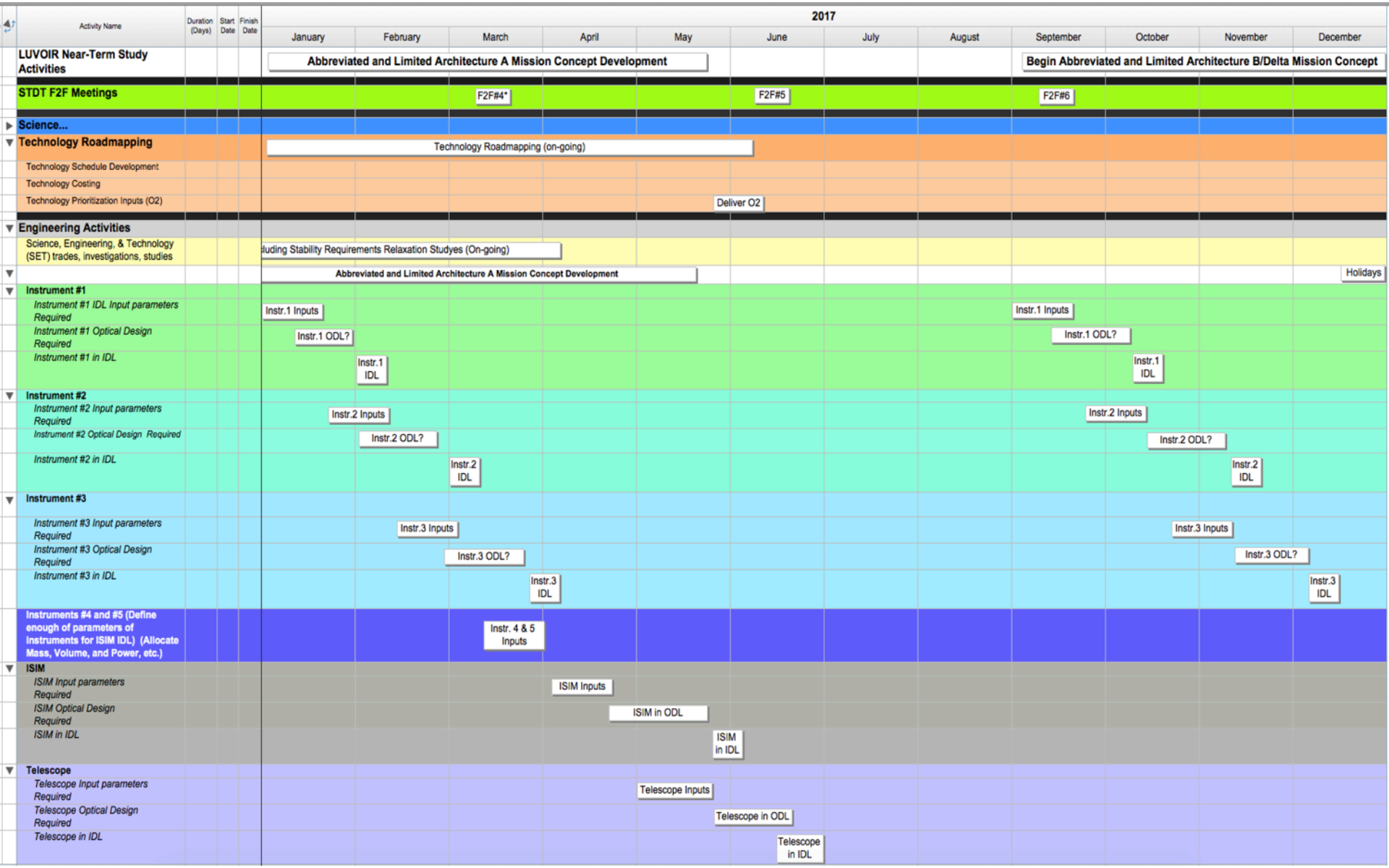


LUVOIR Study Near-Term Schedule (CY16)

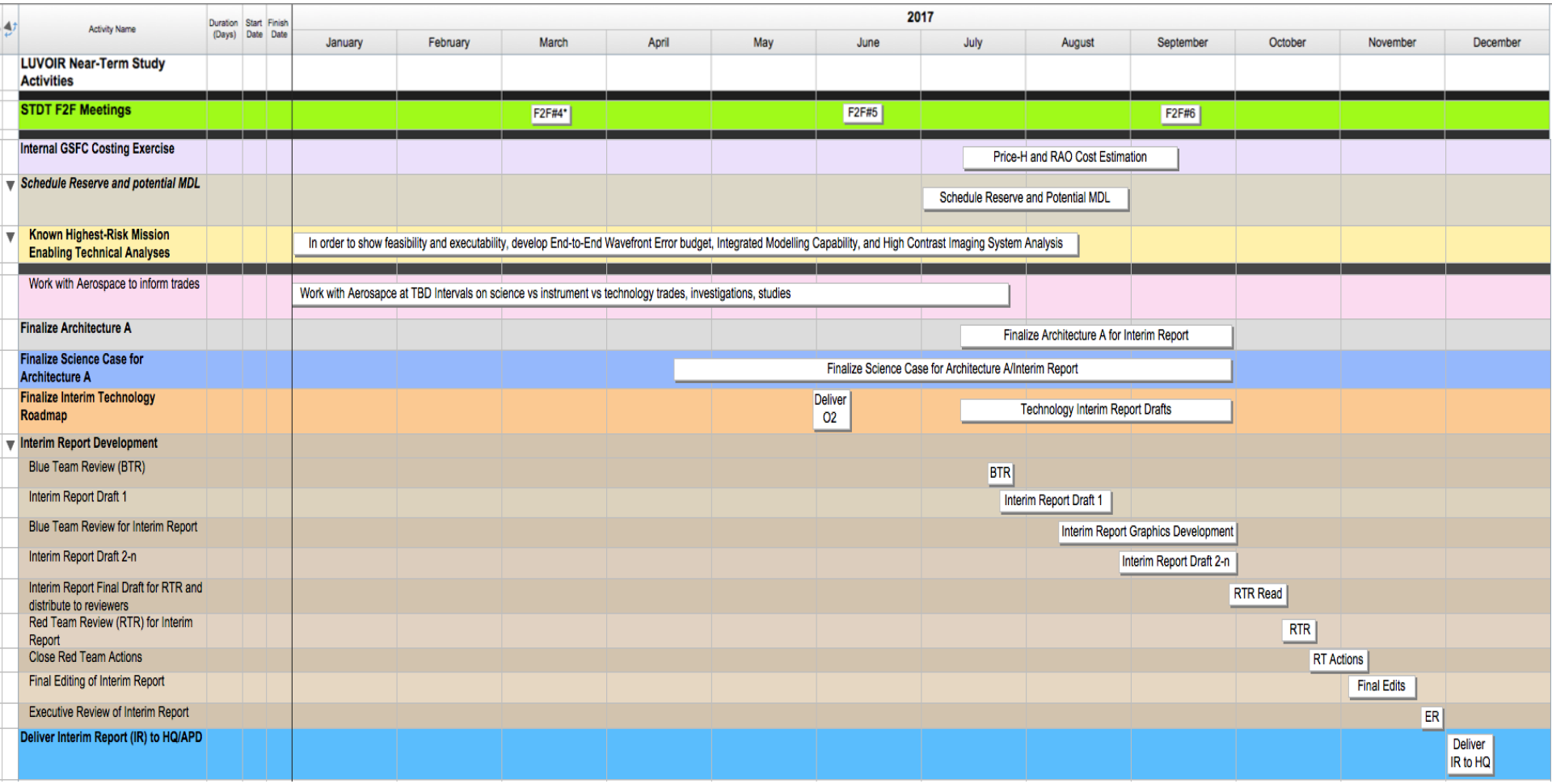


LUVOIR Study Near-Term Schedule (CY17)



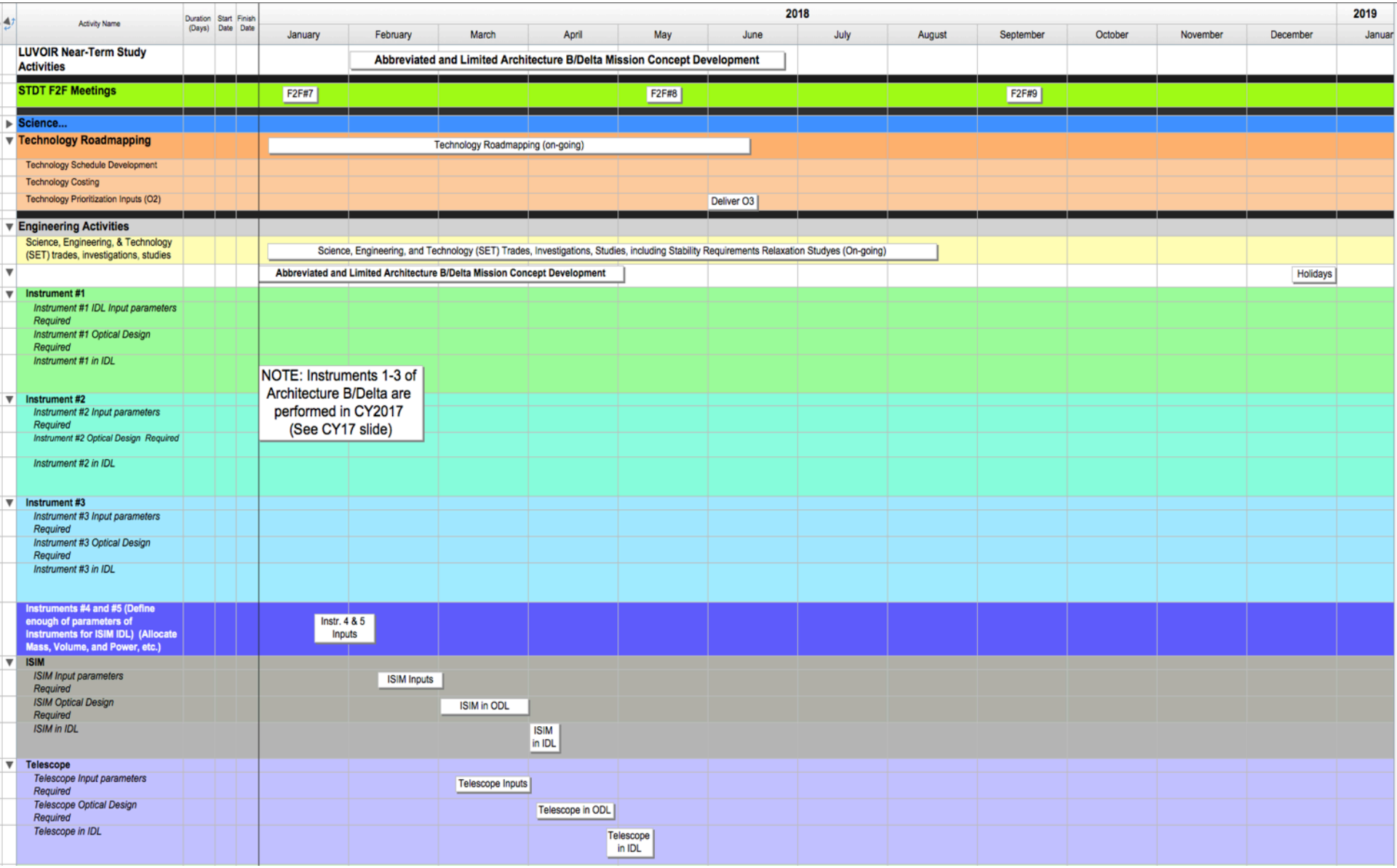
Mission/Instrument Concept Development Architecture A [Note: Architecture study is abbreviated and limited in scope]

LUVOIR Study Near-Term Schedule (CY17)



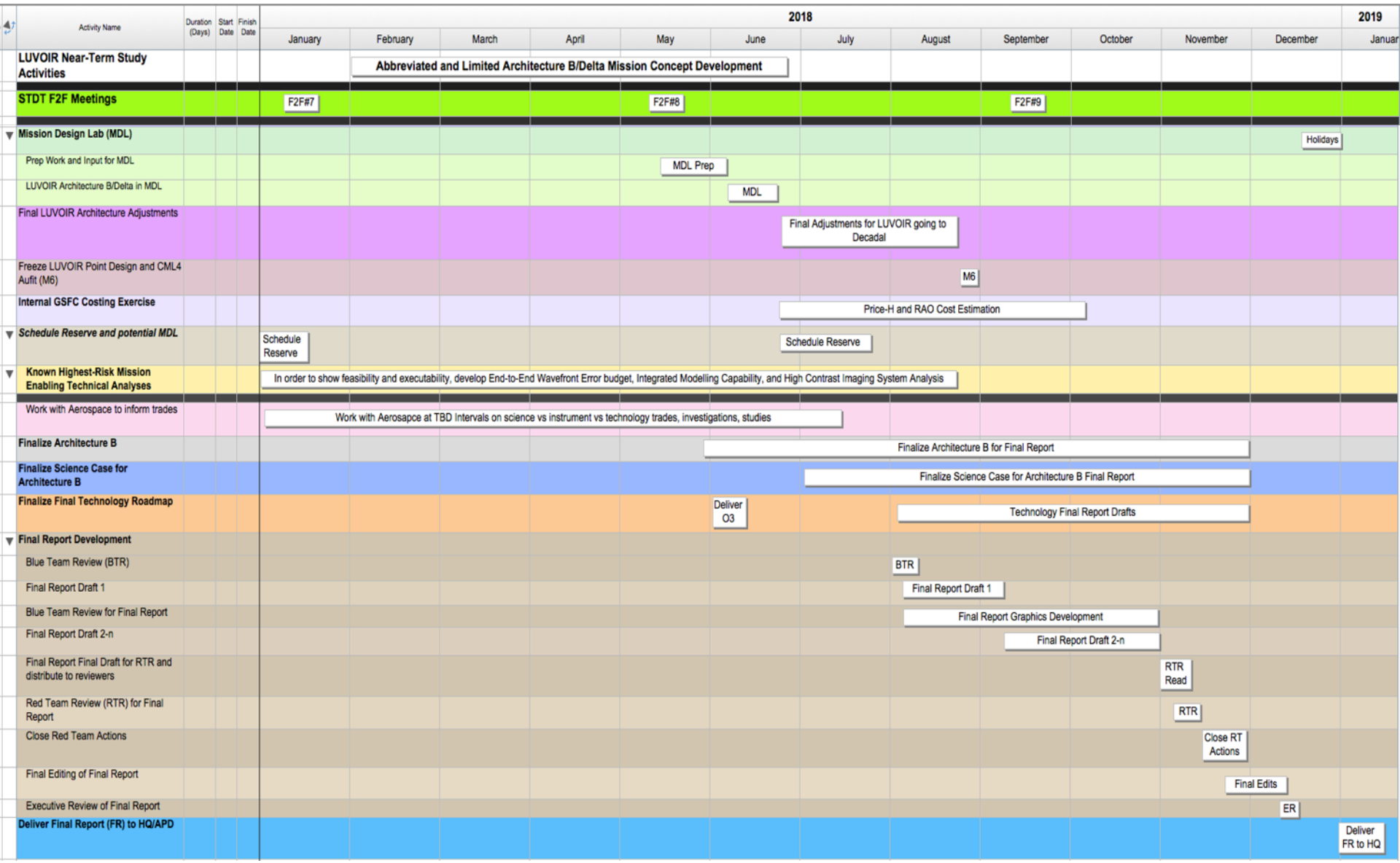
Mission/Instrument Concept Development Architecture A and starting Architecture B at the end of CY17 [Note: Both architectures are abbreviated and limited in scope]

LUVOIR Study Near-Term Schedule (CY18)



Mission/Instrument Concept Development Architecture B/Delta [Note: Architecture study is abbreviated and limited in scope]

LUVOIR Study Near-Term Schedule (CY18)



Mission/Instrument Concept Development Architecture B/Delta [Note: Architecture study is abbreviated and limited in scope]