2 FEBRUARY 2016 NASA AMES RESEARCH CENTER

SOFIA 3D-GEN SCIENCE INSTRUMENT DEVELOPMENT KICKOFF

KICKOFF

S3GSI KICKOFF

AGENDA

- Introductions
- SMD Management Remarks
- SOFIA Program Manager's Remarks
- Scope and Structure of Instrument Concept Study:
    - Executing the Instrument Concept Study
    - ICS Deliverables
    - Requirements for a SOFIA Science Instrument
- Discussion, Q&A

Key personnel

- SMD SOFIA Management Team
  - Dr. Shahid Habib, *Program Executive*
  - Dr. Hashima Hasan, *Program Scientist*
  - Dr. Kartik Sheth, *Deputy Program Scientist*
  - Dr. Erin Smith, *S3GSI Call*
  - Dr. Carlos Liceaga, *TMC Review Lead (LaRC/SOMA)*

- SOFIA Program Management
  - Mr. Eddie Zavala, *Program Manager*
  - Ms. Patricia Daws, *Program Business Manager*
  - Dr. Pamela Marcum, *Program Scientist*
  - Ms. Jeanette Le, *Program Chief Engineer*

- SOFIA USRA Science Mission Operations
  - Dr. Erick Young, *Science Mission Operations Director*
  - Dr. William Reach, *Science Mission Operations Deputy Director*

Key personnel

- NASA SI Development Team
  - Mark McKelvey, *SI Development Manager*
  - Maureen Savage, *USRA SI Development Manager*
  - Jeff Huang, *SI Dev Systems Engineering*
  - Stefan Rosner, *SI Dev Systems Engineering*
  - Eric Burgh, *SI Dev Systems Engineering*
  - Bill Wohler, *SI Software Interface Lead*

- Palmdale Mission Operations Team
  - Bill Latter, *Director of Mission Operations*
  - Zaheer Ali, *Science Lab Manager*
  - Tim Krall, *Science Instrument Airworthiness Team Chair*
  - Ed Ingraham, *SOFIA Safety Lead*

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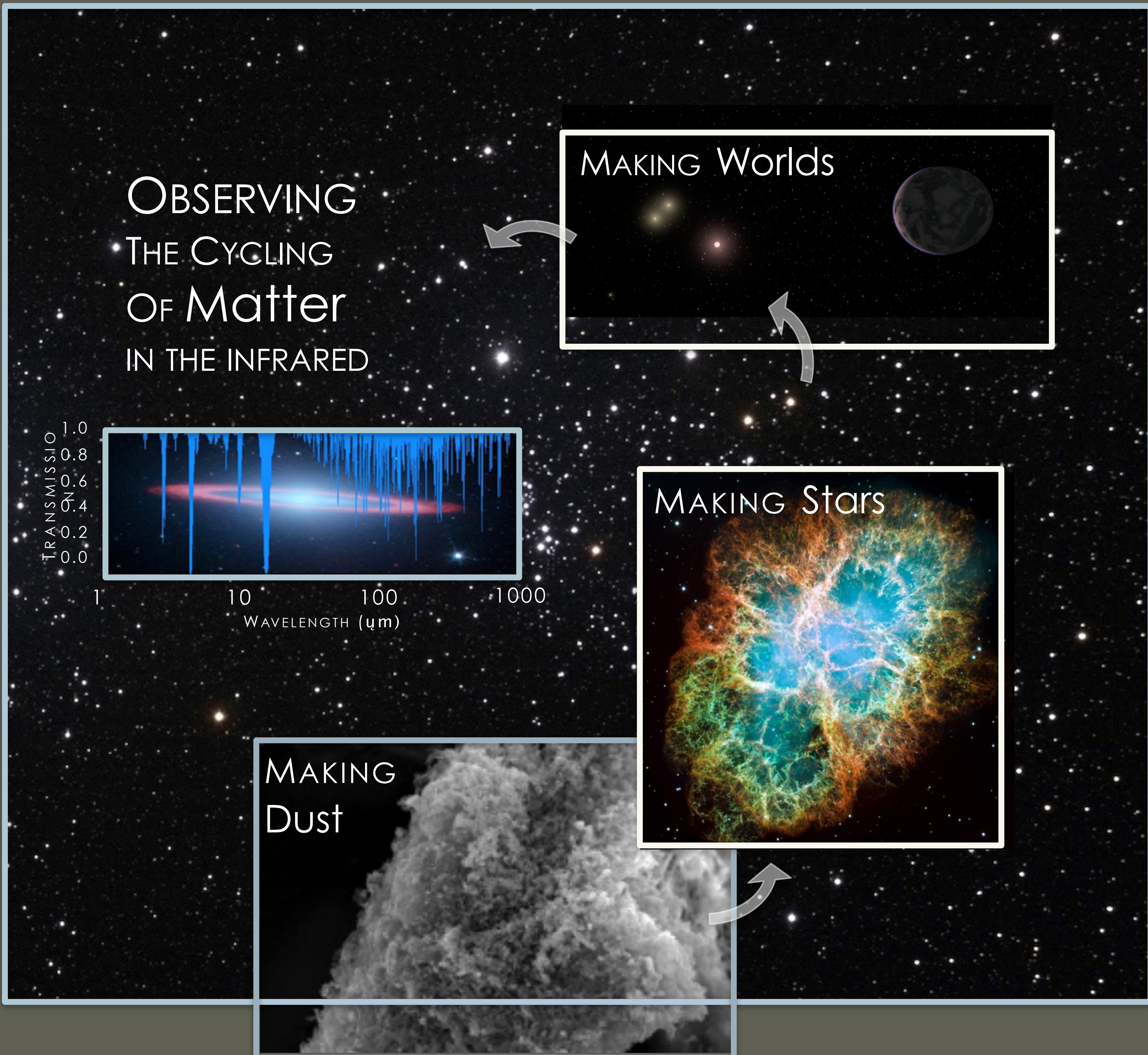


Program Manager's Briefing

February 2, 2016

SOFIA

Stratospheric Observatory for Infrared Astronomy

Presented to:

SOFIA 3rd Generation Science Instrument Concept Study Kick-off

Presented by:

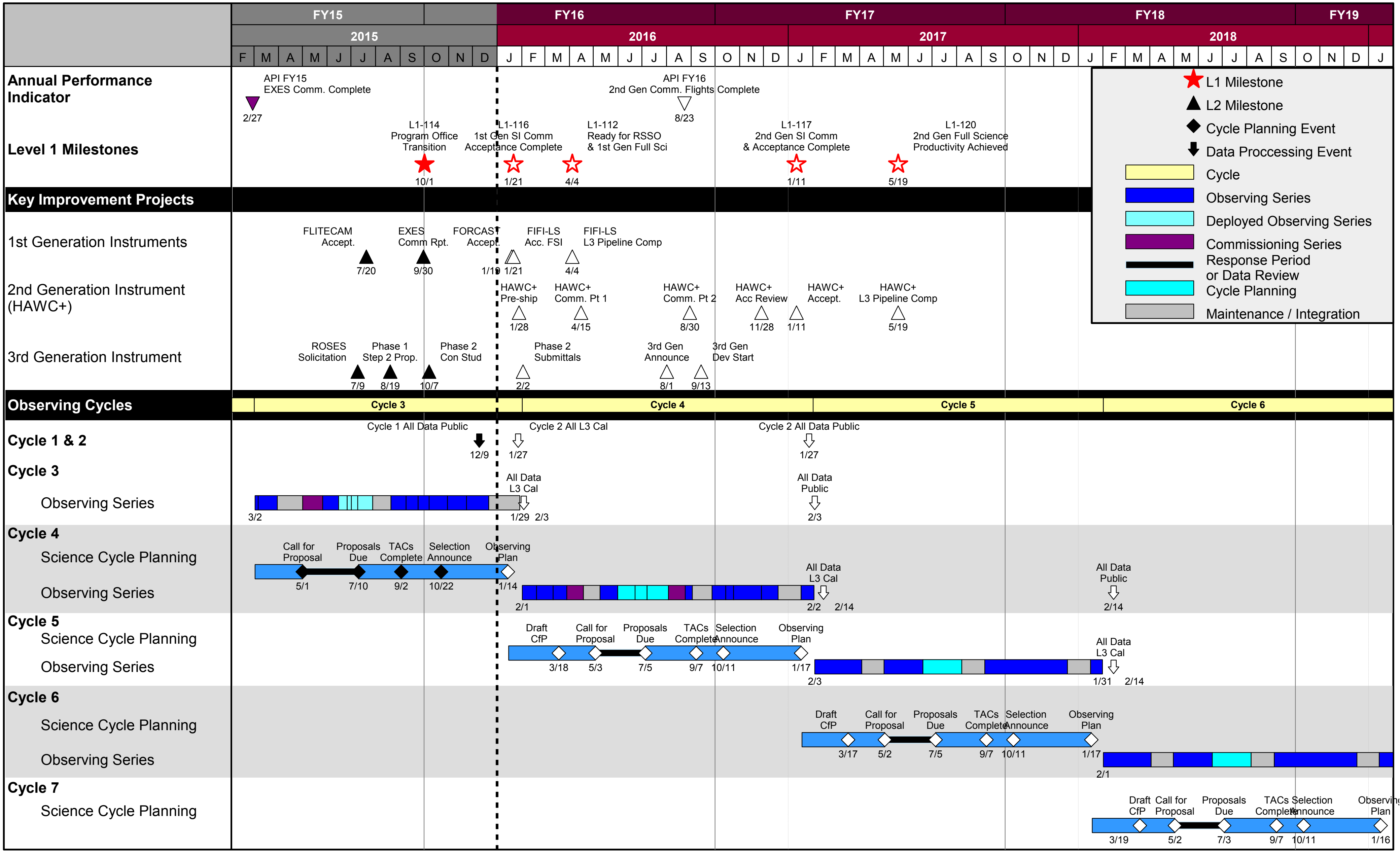
SOFIA Program Manager
Eddie Zavala

The SOFIA observatory studies astronomical observations at wavelengths between 0.3 and 1000 microns

The Key Role of Science Instrumentation

- Science Production primary focus and emphasis will be on scientifically impactful results
- Deployment of new instrumentation is a key component for providing unique scientific capability
- The 3rd Generation Science Instrument will be an essential part of the science instrumentation suite that provides the future perspective for SOFIA
- Establishing a reasonable cadence of new instrumentation is essential to ensuring a relevant, capable science program; starting with the 3rd Generation Science Instrument
- The SOFIA Program is incorporating lessons learned from 1st and 2nd Generation Science Instrument projects to benefit the 3rd Generation Science Instrument project.

SOFIA Top-Level Schedule



Planned Improvements

- Updated / baselined science instrument requirements
- Changed the solicitation approach to provide more mature design at selection
- Opportunity to appropriately streamline and tailor requirements and processes
- At selection, Program-funded support will be provided to the development project team to ensure early identification of potential issues and provide risk-reduction opportunities
  - System Engineering & Integration (SE&I) support
  - Airworthiness support
  - Safety & Mission Assurance support
  - General Engineering support
  - Data pipeline development / transition
- Goal is to ensure smooth, efficient transition from ICS phase into the design life cycle process

Program Governing Authorities

- Programmatic and Technical Management
  - Mark McKelvey, SOFIA Science Instrument Development Manager
- Engineering Technical Authority
  - Jeanette Le, SOFIA Chief Engineer
- System Engineering & Integration
  - Jonathan Brown, SOFIA SE&I Lead
- Science Instrument Airworthiness
  - Tim Krall, SOFIA Operations Engineer
  - Jeff King, SOFIA Operations Center Safety Lead
- Safety and Mission Assurance
  - Ed Ingraham, SOFIA SM&A Lead
- Science Instrument Acceptance
  - Pasquale Temi, SOFIA Facility Scientist
- Science Data Pipeline Acceptance
  - Pam Marcum, SOFIA Project Scientist
  - Erick Young, SOFIA Science & Mission Operations (SMO) Director

Back-up Charts

Cycle 4 Daily Overview - 1 of 2

PMB Approved **Cycle 4 Start**

Maintenance / Upgrade #9								OC#4 A FORCAST																		OC#4 B FIFI-LS								
			FLT (TBD)	MD Rem	SI Install			SI Install	LO	8 Flights															SI Rem	SI Install			SI Install	LO				
S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	H	T	W	T	F	S	S	M	T	W	T	F	S
24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
January -- 2016								February -- 2016																										

OC#4 B FIFI-LS												OC#4 C EXES																	HAWC+ Comm Pt 1					
9 Flights											SI Rem	SI Install			SI Install	4 Flights										SI Rem			SI Install / EMI			LO		
S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S
28	29	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2
	March -- 2016																																	

HAWC+ Comm Pt 1															Maintenance / Upgrades #10																			
	LO	PI - SI Work		3 Commissioning Flights							SI Rem./Install MD				Safety Day																	FLT (TBD)	Rem MD	
S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S
3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4	5	6	7
April -- 2016																												May -- 2016						

	OC#4 D upGREAT																						OC#4 E upGREAT						NZ					
	SI Install		10 Flights																warm				Aircraft Prep				Ferry - 2 flts		Time	Media	Orient	8 Flights		
S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	H	T	W	T	F	S	S	M	T	W	T	F	S
8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	8	9	10	11
May -- 2016																							June -- 2016											

OC#4 E upGREAT		GREAT								OC#4 F FIFI-LS															OC#4 G FORCAST									
	Post	Down/Swap						SI Rem.	Down	SI Install		8 Flights				Post	Down	Prep					SI Rem.	Down	SI Install		8 Flights				Post	Down	Prep	
S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S
12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
June -- 2016																			July -- 2016															

OC#4 G FORCAST																	HAWC+ Comm Pt 2																	
			Post	Down	Prep			Ferry		SI Rem.	Crew Rest				Crew Rest		SI Install					LO	Prep	LO					3 Commissioning Flights					
S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S
17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
July -- 2016															August -- 2016																			

Key Observing cycle: 4 *Planned science flights: 101* *RHs*: 808* ** Max available research hours*

S / 7	**Weekend day** (black text with no fill)	H / 4	**US or German Holiday** (day of week box H or GH w/ red fill)	F / 6	**Instr. Commissioning Flight** (bold white text, purple fill, bold border)
F / 6	**Observing Flight** (bold white text, blue fill, bold border)	F / 6	**Ferry/Maint./Non-Sci Flight** (bold white text, green fill, bold border)	F / 6	**Educator on Flight** (white star on day of week)
F / 6	**Return to Base (RTB) Flight** (single slash through day and date)	F / 6	**Work day** (black text w/ day box grey fill)	F / 6	**Line Operations** (bold border)
F / 6	**Contingency Instr. Comm. Flight** (day box with purple fill)	F / 6	**Contingency Obser. Flight** (day box with blue fill)	F / 6	**Contingency Ferry/Maint./Non-Sci Flt** (day box with green fill)
F / 6	**Media/VIP on Flight** (yellow star on date)	F / 6	**Canceled Flight** (x through day and date)	F / 6	**AFRC Regular Day Off** (day and date shown in red)
F / 6	**Possible Maint/Up. Check Flt** (day and date box filled with lt. green)	F / 6	**Deployment Observing Flights** (bold white text, light blue fill, bold border)	S / 28	**Short Flight** (colored fill only lower half, bold bdr.)
S / 13	**Half Sci. & Half Ferry/Maint./Non-Sci** (two colored fill)	√	**Restored Flight** (check mark below day)	U	**Notional Unfunded Flight** (yellow fill with U below day)

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SOFIA Third Generation Instruments

Concept Study Kickoff Meeting
February 2, 2016

Astrophysics

Hashima Hasan
SOFIA Program Scientist

Science Mission Directorate
NASA Headquarters

ICS Report Evaluation Process

- The Science Office of Mission Assessments (SOMA) at LaRC has been tasked with conducting a technical, management and cost (TMC) evaluation of the two ICS Reports.
- The Acquisition Manager is Carlos Liceaga
- Concept Study Reports are due on July 19, 2016
- The Evaluation process is as follows
  - Evaluation will include a meeting at a neutral site where the teams will have an opportunity to present the results of their study to the review board.
  - A list of potential major weaknesses will be delivered to the team by 5 pm, three days in advance of this meeting. The teams should prepare to address these issues during their presentation.
  - The review board will provide a list of their findings (strengths and weaknesses) to the SOFIA Program Scientist.
  - **The review board will ask for overall risk rating of the reports, not will they be asked for a selection recommendation.**

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ICS Report Evaluation Process

- A selection committee of Civil Servants, chaired by the SOFIA Program Scientist will consider the ICS Reports, the findings from the Science Evaluation, and Technical, Management and Cost evaluations and craft a recommendation to the Selecting Official.
- Selecting Official will consider the ICS Reports, the findings from the Science Evaluation, and Technical, Management and Cost evaluations and selection committee recommendation, in making his decision.
- Teams will be notified of NASA's selection decision by early September 2016.

N.B. Since the two teams are from NASA Centers, communication channels are open with the NASA management. Information will be shared with both teams to maintain transparency.

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ICS Report Evaluation Factors

1. Scientific Merit of the Investigation

The SOFIA Program Scientist and Deputy Program Scientist will determine whether any issues that may have emerged in the course of the ICS have effected significant changes to the science objectives that were the basis of the peer review panel's rating of the scientific merit of the Step 2 proposal.

If there are no significant changes to the proposed investigation that undermine the basis of this rating, the peer review panel's findings with regard to science merit of the ICS report will not be revisited.

If there are significant changes, the Program Scientist will conduct a peer review to reevaluate the scientific merit of the objectives in light of these changes. The factors for reevaluating this criterion will be the same as those used for the Step 2 proposal review.

ICS Report Evaluation Factors

2. Scientific Implementation Merit and Feasibility of the Investigation

Evaluation will consider the following factors:

- Merit and maturity of the instrument design for addressing the science goals and objectives.
- Technology readiness level of critical sub systems at TRL 6.
- Technology readiness level of integrated system end-to-end at TRL 6.
- Overall architecture is established with a clear path of technology infusion
- Adequacy of the instrument to conform and meet SOFIA Observatory requirements
  - Maturity of proposed Level 0 requirements (Project success criteria) and Level 1 project requirements.
- Team's ability to effectively integrate the subsystems and deliver within cost and schedule
- Merit of the data reduction, analysis, and availability
- Clear path forward to produce science results
- Likelihood of instrument output that will ensure high value science as specified

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ICS Report Evaluation Factors

3. Feasibility of Instrument Implementation, Including Cost Risk

Evaluation will consider the following factors:

- Adequacy and robustness of instrument implementation plan.
- Adequacy and robustness of the plan for instrument operations.
- Adequacy and robustness of instrument accommodation, including interfaces to SOFIA Observatory.
- Adequacy and robustness of the management approach, including the capability of the management team, adequacy of the proposed approach; the organizational structure, the roles and experience of the known partners; the commitments of partners and contributors; the team's understanding of the scope of work (covering all elements of the mission, including contributions).
- Adequacy and robustness of the schedule, including the relationship of the work to the project schedule, the project element interdependencies, and associated schedule margins will also be evaluated.

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ICS Report Evaluation Factors

- Adequacy and robustness of the cost plan, including evaluation of underlying rationales for the cost estimates, including reserves, and the development schedule, including schedule margins; adequacy of reserves; identification of cost risks; the credibility and realism of the cost estimates and the planned financial resiliency.
- Adequacy of the risk management plan, including safety.
- Adequacy of instrument pipeline, calibration and commissioning plans (sections 5.6.3 and 5.7 of solicitation).
- Maturity of systems requirements.
- Adequacy of management plan for instrument development at the Preliminary Design level and culminating in CDR.

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ICS Evaluation Schedule

- Funding in Place: January 19, 2016
- Kick off @ARC: February 2, 2016
- SRR (locations TBD): March 15-18, 2016
- Formal CSR Delivered: July 19, 2016
- TMC deliberations, including PI meeting: July 21-mid August, 2016
- Selection Committee Meeting at HQ: August, 2016
- Announcement to PIs: NLT September 1, 2016
- Implementation phase begins: NLT September 1, 2016
- PDR: NLT November 1, 2016
- CDR: NLT July 17, 2017
- Instrument Integration complete: NLT August 15, 2018
- Instrument Testing: NLT October 1 – November 30, 2018
- Instrument Delivery: NLT December 28, 2018

Technical, Management and Cost (TMC) Evaluation Process

Dr. Carlos A. Liceaga, P.E.

SOFIA Acquisition Manager

NASA Science Office for Mission Assessments

February 2, 2016

What is evaluated?

Total Risk of Science Flight Investigation

- **Inherent Risks**
- **Programmatic Risks**
- **Implementation Risks Evaluated by TMC**

Risks that are unavoidable
to do the investigation:
- Launch environments
- Space environments
- Mission durations

Risks that are uncertainties due to matters beyond project control:
- Environmental Assessment approvals
- Budgetary uncertainties
- Political impacts
- Late/non-delivery of NASA provided project elements
- Stability and reliability of proposed partners and their contributions

Risks that are associated with implementing the investigation:
- Adequacy of planning
- Adequacy of management
- Adequacy of development approach
- Adequacy of schedule
- Adequacy of funding
- Adequacy of Risk Management (planning for the known and unknown)

Evaluation Principles

- Basic Principles:
  - It is assumed that the proposer is the expert on his/her proposal.
  - Proposer's task is to <u>demonstrate</u> that the investigation implementation risk is low.
  - TMC panel's task is to try to <u>validate</u> proposer's assertion of low risk.

- Merit is to be assessed on the basis of material in the proposal. All Proposals are evaluated to identical standards and not compared to other proposals.

- TMC Panels consist of evaluators who are experts in the factors that they evaluate.

- TMC Panels develop findings for each proposal - Findings: "As expected" (no finding), "above expectations" (strengths), "below expectations" (weaknesses). Risk Ratings reflect the written strengths and weaknesses.

- The Cost Analysis is integrated into the overall Risk Rating.

Findings

Major Strength: A facet of the response that is judged to be well above expectations and can substantially contribute to the ability to meet technical commitments on schedule and within cost.

Major Weakness: A deficiency or set of deficiencies taken together that are judged to substantially affect the ability to meet the proposed technical objectives within the proposed cost and schedule.

Minor Strength: A strength that is substantial enough to be worthy of note and brought to the attention of study team in debriefings.

Minor Weakness: A weakness that is substantial enough to be worthy of note and brought to the attention of study team in debriefings.

Note: Minor points can influence risk ratings.

Cost Evaluation Process and Elements

5. Overall Cost Realism Rating
H,M/H,M,M/L,L

4. Cost Evaluation Summary

3. Cost Threats
from all work below

2. Independent Tools
models, analogies

1. Analysis of
Proposals

Cost Risk Definitions

Cost Risk	Definition
LOW	***Cost Envelope is adequate – expect success.*** - The proposer's estimate *(with reserves)* agrees closely with the work, staffing, and schedule proposed, fits within the program cap and any other budget constraints, and is verified by TMC independent analysis. - The proposed cost reserve is adequate to address cost threats identified by TMC, and to fund unexpected needs. - The resource management plan indicates strong, active management of resources throughout implementation.
LOW/ MEDIUM	***Cost Envelope is somewhat tight, but project should succeed.*** - TMC identified one or more significant cost threats or weaknesses with regard to the proposer's estimate, cost reserves, and/or resource management. Overall impact of identified threats and weaknesses should be manageable. - TMC independent analysis verifies proposer's costs.
MEDIUM	***Cost Envelope is tight. Success requires diligent oversight of resources.*** - TMC identified one or more significant cost threats or weaknesses with regard to the proposer's estimate, cost reserves, and/or resource management. Cost impact of threats may be underestimated by proposer. Overall impact of identified threats and weaknesses should be manageable. - TMC independent analysis verifies some or most of proposer's costs.
MEDIUM/ HIGH	***Cost Envelope is very tight. It is likely the project will require more funding.*** - TMC identified one or more major cost threats or weaknesses with regard to the proposer's estimate, cost reserves, and/or resource management. Cost impact of threats appears underestimated by proposer. Overall impact of identified threats and weaknesses will be challenging to manage within funding and/or schedule constraints. - TMC independent analysis could not verify significant elements of proposer's costs.
HIGH	***Project exceeds the Cost Envelope and is expected to require substantially more funding.*** - TMC identified one or more major cost threats or weaknesses in the proposer's estimate, cost reserves, and/or resource management. Overall impact of identified threats and weaknesses exceeds proposed resources and/or available resources to cover them. Threats are not acknowledged, or are underestimated by proposer. - TMC independent analysis could not verify proposer's costs.

Risk Ratings Definitions

The purpose of the TMC evaluation is to assess the likelihood that the submitted investigations' technical and management approaches can be successfully implemented as proposed, including an assessment of the likelihood of their completion within the proposed cost and schedule.

Based on the narrative findings, each proposal will be assigned one of three Risk Ratings:

- **Low Risk:** There are no problems evident in the proposal that cannot be normally solved within the time and cost proposed. Problems are not of sufficient magnitude to doubt the Proposer's capability to accomplish the investigation well within the available resources.

- **Medium Risk:** Problems have been identified, but are considered within the proposal team's capabilities to correct within available resources with good management and application of effective engineering resources. Mission design may be complex and resources tight.

- **High Risk:** One or more problems are of sufficient magnitude and complexity as to be deemed unsolvable within the available resources.

Envelope Concept

Envelope: All TMC resources available to handle known and unknown development problems that occur. Includes schedule and funding reserves; reserves and margins on physical resources such as mass, power, and data; descope options; fallback plans; and personnel.

Low Risk: Required resources fit well within available resources

Medium Risk: Required resources just barely inside available resources.

High Risk: Required resources DO NOT fit inside available resources.

- The acquisition web site address is: http://soma.larc.nasa.gov/sofia/
- All reference documents are available in the Program Library on this website. It currently includes:
  - 2 Handbooks
  - 12 Science Instrument (SI) to Aircraft Systems ICDs
  - 3 SI to Ground Systems Interface Control Documents (ICDs)
  - 4 Specifications
  - 5 Support Documents
- Answers to questions submitted by either team will be posted to this website

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S3GSI KICKOFF

ICS SCOPE AND STRUCTURE

- ICS Ground Rules
- Review of Solicitation
- ICS Deliverables
- ICS Audience
- Timeline for Concept Study

S3GSI kickoff: ICS Scope

ICS ground rules

- *ICS competition and selection managed by SMD/APD.*
- SOFIA provides technical and programmatic support.
- Competitive Selection, 'light touch' management to minimize Program influence.
- *Questions always welcome…..*answers to common questions posed will be shared with both teams.
- A website has been established for updated guidance.
- Updated information online at:

http://soma.larc.nasa.gov/sofia/

ICS ground rules

- Document Library contains definitive information on Program requirements and guidance:
  - ***Science Instrument Developers' Handbook***
  - ***Science Instrument System Specification '2028'***
  - **Requirements Verification Matrix Template**
  - *SOFIA Concept of Operations*
  - *Data Processing Plan for SOFIA Science Instrument*
  - *SOFIA Command Language (SCL) User's Manual 'SCLUM'*
  - *Ground and Aircraft System Interface Control Documents (ICDs)*
  - *Telescope, Cryocooler, and Vacuum Pumping System Specifications.*
- International participation is on a no-exchange-of-funds basis.
- ***Concept Study Report due by electronic submission via NSPIRES 11:59pm EDT, 19 July 2016***

Review of Solicitation

- Overall intent:
  - Identify a specific SOFIA scientific goal.
  - Propose a scientific investigation to address that goal.
  - Design, build, and deliver a science instrument enabling that investigation.
- Proposals to address (at minimum):
  - Instrument design and fabrication, including a high-level preliminary schedule and cost estimate.
  - Development of instrument control, data reduction, and analysis pipeline software and algorithms.
  - Expected instrument performance.
  - All phases of instrument development: Concept Study, Implementation, Delivery, Commissioning, Acceptance, GTO Science, and any required post-delivery support.

Review of Solicitation

- The 3d-Gen SI will be a Facility-Class Instrument:
  - Delivered to and accepted as a NASA-owned asset for GI Science.
  - In operation, observing time will be awarded competitively by TAC.
  - It is anticipated that the instrument award will include an allocation of time for a GTO program during the initial operating period.
  - Observatory capabilities are summarized in "*The SOFIA Observatory at the Start of Routine Science Operations: Mission capabilities and performance,*" Pasquale Temi, et al, Astrophys. J. Suppl. 212, 24, 2014.
- Development budget through acceptance is limited to ~$17M. More detailed guidance available in website FAQ.
- Actual development budget/schedule to be developed by ICS Teams.

Review of Solicitation

- **A note on pipelines**:
  - The solicitation text contradicts some of the pipeline requirements in the SOFIA document library.
  - Solicitation states:
    'The development and delivery of functioning algorithms, and associated supporting documentation, that can be used by the SOFIA Science Mission Operations Center (SMOC) staff to develop an in-house pipeline is a required component of the selected instrument.'
  - Doc library requires SI-delivered pipeline. This deliverable is waived in this instance, but team may still choose to develop pipeline for demonstration of calibration plan and algorithms.
  - Team selected for implementation will work closely with SMOC during implementation as SMOC develops pipeline. ICS Team to provide demonstrated algorithms and clear links to commissioning plan.
  - CSR will clearly demonstrate how SI team would approach pipeline requirements, including appropriate budget and scheduling milestones.

ICS Deliverables

Per the solicitation, the primary deliverable is:

'A Preliminary Design-level description of the instrument, including both its flight software and the necessary ground data processing software, a preliminary instrument calibration and commissioning plan, the development management plan, a more detailed cost estimate, and a more detailed development schedule. A detailed management plan for the development of the selected instrument shall be developed during the ICS.'

ICS Deliverables

Interpretation:

- The *Preliminary Design Description* will be submitted as a Concept Study Report (CSR).
- The CSR will be a electronically submitted for review via NSPIRES at the end of the ICS phase.
- Following TMC evaluation, a meeting at a neutral site will be held, to allow each team to present highlights of its study report and to respond to comments from the initial TMC evaluation.

ICS Deliverables

The CSR goal is a 'PDR-ready' design level description of the instrument, addressing:

- *Top level architecture of SI, subsystems, and external interfaces (block diagram)*
- *Instrument hardware description*
- *Flight software*
- *Pipeline data processing software*
- *Instrument calibration and commissioning plan*
- *Systems engineering process and management plan for the development phase*
- *Risks identification and mitigation plan*
- *Detailed cost estimate*
- *Detailed development schedule*
- *Description of design aspects subject to further definition*
- *Compelling evidence of TRL6 or higher for all aspects*
- *Demonstrated understanding of and compliance with all scientific, technical, documentation, and programmatic requirements.*

SEE IDHB FOR DETAILED PDR REQUIREMENTS

ICS Deliverables

- We recognize that a full PDR during ICS isn't feasible.
- To reach the desired timetable, we need the CSR to be as PDR-ready as is practical.
- As a preparatory step to 'PDR-ready', an SRR will be held during the ICS to establish that requirements are understood.
- By holding the SRR during ICS we leverage the (now six-month) ICS period toward accelerated implementation.
- SRR and PDR criteria are detailed in the Instrument Developer's Handbook.

ICS Deliverables

A successful PDR for SOFIA requires (IDHB highlights):

- *Preliminary design meets requirements at an acceptable level of risk*
- *Definition of technical interfaces provides an acceptable level of risk*
- *Technology has been developed to an adequate state of readiness*
- *Flowdown of verifiable requirements is complete*
- *Risks are understood and have been credibly assessed*
- *Safety and mission assurance have been adequately addressed*
- *Demonstration of adequate technical and programmatic margins.*
- *Operational concept is technically sound.*
- *Technical trade studies are mostly complete*
- *Demonstrated compliance with requirements, standards, processes*
- *TBD and TBR items clearly identified*
- *Appropriate modeling and analysis results are available*
- *Heritage designs have been suitably assessed for applicability*
- *A conceptual test and evaluation strategy has been formed*
- *Manufacturability has been adequately included in design.*
- *Software components are being developed per the SOFIA SMP*

ICS Deliverables

During the ICS phase:

- Teams will submit short (not more than three pages) progress reports to the SI Dev Manager on four week intervals.
- The System Requirements Review will be held with each team separately, early in the ICS period. Target is mid-late March 2016, details will be worked out with ICS teams.

ICS audience

- Two audiences , Technical, Management and Cost (TMC) review panel (primary), and SOFIA staff for early RFI/RFAs.
- TMC review criteria are spelled out in SMD presentation above.
- SOFIA review criteria are the results of the SRR and PDR-ready CSR, as specified above.

CSR Content

Section	Page Limits
A. Graphic Cover Page	1
B. Fact Sheet/Executive Summary	2
C. Table of Contents	No page limit
D. Science (including GTO time estimate)	5
E. Science implementation including: - Detailed design description - Instrument commissioning - Management & schedule	50 (excluding schedule foldouts)
F. Cost Proposal / budget narrative	No page limit
Appendices 1. Resumes 2. SoW for remaining work 3. Draft requirements compliance matrix (including airworthiness requirements) 4. Acronyms and Abbreviations 5. Heritage 6. Master Equipment list (MEL) 7. Facilities 8. References*	No page limit, but small size encouraged

CSR Content

- Project
  - Deliverables
  - Level 1 requirements / success criteria
  - Team organization – roles & responsibilities, org chart
  - Top-level schedule showing key milestones and critical path
  - Key metrics along with current best estimates, contingencies, margins
  - Key challenges, interfaces, constraints
  - Facility (including major support equipment) requirements
  - Status of action items (response to findings) from Req. Review
  - Status of MOUs and agreements, if any
  - Configuration management approach & plan

CSR Content

- Systems Engineering
  - Performance Requirements
    - Level 2 (Level 3) requirements flow down
    - Key & driving requirements and their verification approach
    - Requirements compliance check
  - Interface Requirements
    - Optical, Mechanical, Environmental, Electrical, Software, Data ICDs and status
  - Verification of Level 1 requirements
  - Results of major design trade-offs; outstanding trades, if any
  - Status of risk reduction hardware and testbeds, if any
  - Risk management process, risk list & mitigations
  - Descopes and decision date, if any
  - Project document tree and documentation plan
  - Drawing tree

CSR Content

- Science
  - Science, experiment and instrument performance models
  - Calibration plan
  - Changes if any since Step 2 proposal should be clearly identified.

- Instrument
  - Requirements, block diagram & architecture
  - Error budgets for key parameters
  - Description & build approach – what's new, inherited, procured
  - Long lead procurement and status
  - Performance capabilities and margins
  - Technical resources, contingencies and margins
  - Integration and test concept
  - Requirements verification plan

CSR Content

- Operations and Data Management
  - Operational requirements, modes & scenarios
  - Plan for development and delivery of functioning algorithms for a pipeline, and associated supporting documentation
  - Levels 0-2 product description, data rate/volume & processing needs

- Safety & Quality Assurance
  - NASA, Institutional and Project requirements
  - Environmental requirements along with design, analysis and test plan
  - Instrument life assessment – life limiting elements & spares, time to recover from failures
  - Servicing and maintenance concept

CSR Content

- Path to completion of detailed design
- Draft End-to-end I&T + verification plan
- Preliminary commissioning plan
- Risk Identification and mitigations
- Detailed Schedule
- Detailed Cost
  - Basis of estimate
  - Cost breakdown by WBS, month, phase
  - Cost savings for identified descopes

S3GSI kickoff: ICS Scope
ICS timeline

- SRR (locations TBD): March 15-18, 2016
- Formal CSR Delivered: July 19, 2016
- TMC deliberations, including PI meeting: July 21-mid August, 2016
- TMC plenary and Final Report to HQ: Aug 22, 2016
- Selection Committee Meeting at HQ: August, 2016
- Announcement to PIs: September 1, 2016
- Implementation phase begins: September 1, 2016
- PDR: November 1, 2016
- CDR: July 17, 2017
- Instrument Integration complete: August 15, 2018
- Instrument Testing: October 1 – November 30, 2018
- Instrument Delivery: December 28, 2018

Business Details

- Funding is provided by the SOFIA Program Office
  - Direct funds transfer to GSFC, Task Order obligation to JPL
- ICS funded up to $400K, ~6 months
  - Initial funding made available January 19, 2016 ($200K)
  - Additional funding will be distributed upon receipt of ICS cost and schedule information
    - Distribution of remaining funds will be made as needed, or as soon as SOFIA program receives full budget authority from HQ
- SOFIA POC for funds distribution/availability: Patti Daws
  - patricia.r.daws@nasa.gov
  - (661) 276-2964
- Key SMD milestones will be tracked in the SOFIA IMS, including SRR dates
- Lower level of detail/schedule information will not be tracked in the SOFIA IMS

Science Instrument Developers' Handbook
SCI-AR-HBK-OP03-2000 Rev. B
Walkthrough

Jeff Huang
SOFIA Science Instrument Development Group

Feb. 2 & 3, 2016

SOFIA 3rd Generation SI Kickoff Meeting

Handbook Overview

- The *SOFIA Science Instrument Developers' Handbook* provides an overview of the SOFIA instrument program and references all the necessary SOFIA requirements and interface documents which apply to science instruments.
- The handbook is not a requirements document.
- Revision A (June 2015) of the handbook was included in the SOFIA Document Library with the SOFIA 3rd Generation Science Instrument solicitation.
- Revision B (January 2016) of the handbook has since been developed—clarifying and providing additional details about SOFIA processes. Revision B is currently in signature; a draft has been included in the updated SOFIA Document Library, available at: http://soma.larc.nasa.gov/sofia/sofialib.html
  - Rev. B section / paragraph numbers are cited in these briefing charts
- This handbook is frequently referred to as "IDHB" in these briefing charts.

Rev. B Change Highlights

- Highlights of the changes made in Rev. B are listed below (***IDHB Appendix H*** contains a complete list of changes):
  - New sections have been added providing details of Pre-Shipment verification activities including: Airworthiness Inspections, SE&I Verification, Instrument Software-MCCS Testing, Instrument Data Product-DCS Testing, and Instrument Data Reduction Pipeline-DPS Testing.
  - New sections have been added providing entrance criteria for milestone/ technical reviews including: SRR, PDR, CDR, Pre-Shipment Review, Pre-Installation Review, and Acceptance Review.
  - Several SOFIA “Plan” reference documents have been added, some replacing old out-of-date plans; the new plans referenced are: SOFIA Software Management Plan (SOF-DA-PLA-PM20-2011), SOFIA Software Assurance Plan (SOF-NASA-PLA-PM21-2091), SOFIA Quality Plan (SOF-NASA-PLA-PM21-2090), SOFIA Safety Plan (SOF-NASA-PLA-PM21-2089), and SOFIA Program Mishap Preparedness and Contingency Plan (SOF-DF-PLA-OP05-2000).

Rev. B Change Highlights [cont.]

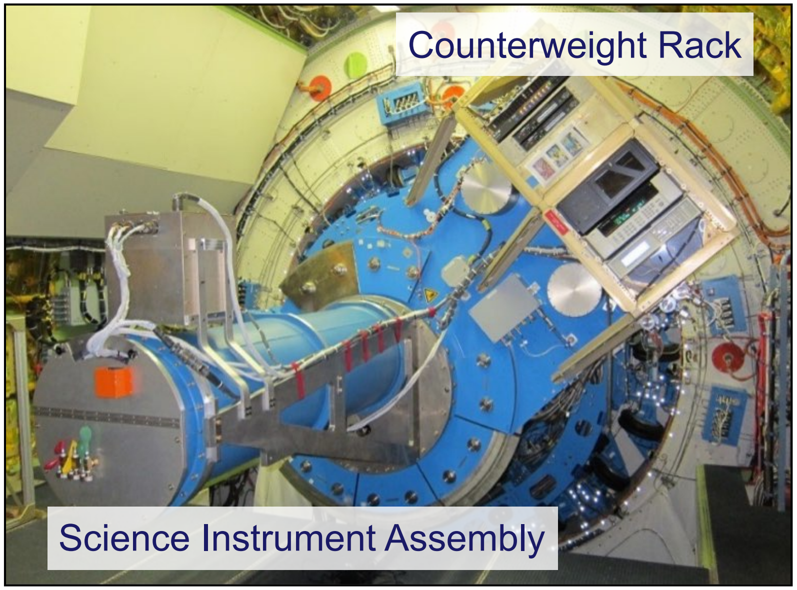
- Appendix A has been renamed to “Appendix A.1 Deliverable Items List”.
- Several items have been added/formalized as document deliverables in Appendix A.1—these are items that were previously implicit deliverables required for the SI to show compliance with SOFIA requirements. The items are: Software requirements verification matrix, SI mass and C.G. ICD analysis report, Instrument ICD envelope analysis report, Instrument cart/stand ICD analysis report(s), Instrument cart/stand structural analysis report(s), Cryogen fill procedure.
- Appendix A.2 Documentation Delivery Schedule has been added summarizing when document deliverables are due.
- Samples of the four generic SI Hazard Reports have been added.

IDHB Table of Contents

SOFIA Science Instrument Developers' Handbook
SCI-AR-HBK-OP03-2000, Rev. B (Draft; In signature)

SI System Hardware Components [4.1]

- ***Section 4.1*** describes the primary SI System hardware components:
  - Instrument Assembly
  - Counterweight Rack (CWR)
  - PI Rack(s)
  - Installation Cart
  - Any Pressure Coupler
    or Optical Window Assembly
  - Any Lab cart/stand
    or ancillary equipment



Government Furnished Equipment (GFE) [4.3]

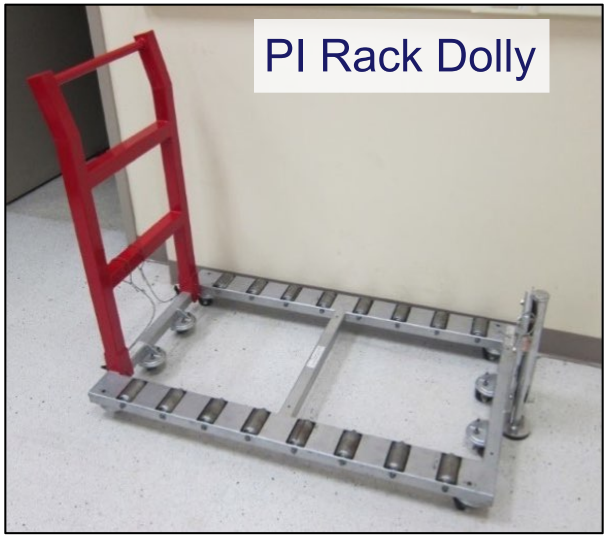
Provided and shipped to Instrument Developer:

– Principal Investigator Rack(s)
– Counterweight Rack

Resources available at AFRC B703 Ground Facility and SOFIA for use by SI:

– Laboratory space
– Telescope Assembly Alignment Simulator (TAAS)
– Cryogens
– Vacuum pumps
– Cryocooler compressor
– PI Rack dolly
– Counterweight Rack cart
– Auxiliary Rack
– Secondary mirror buttons
– Technicians and supplies to support integration

Government Furnished Equipment (GFE) [4.3] [cont.]

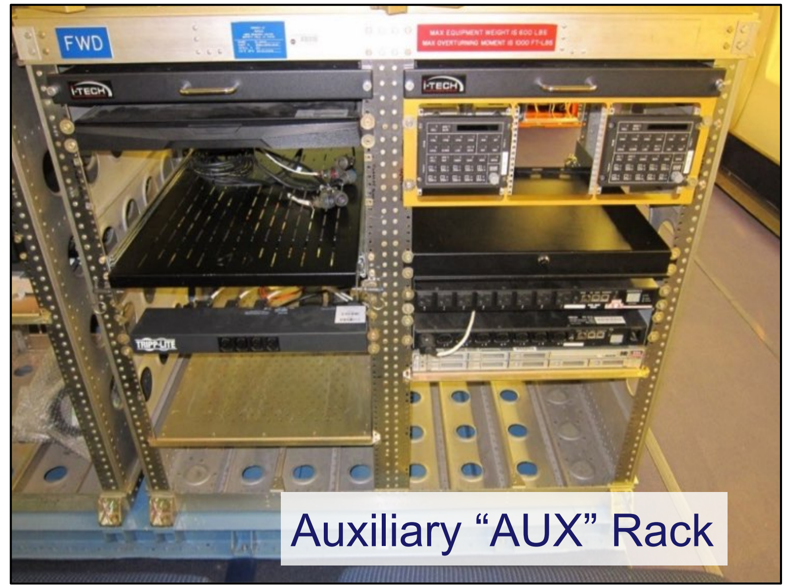

PI Rack Dolly


Counterweight Rack Cart

Lab Hoist / Lifting Ground Support Equipment

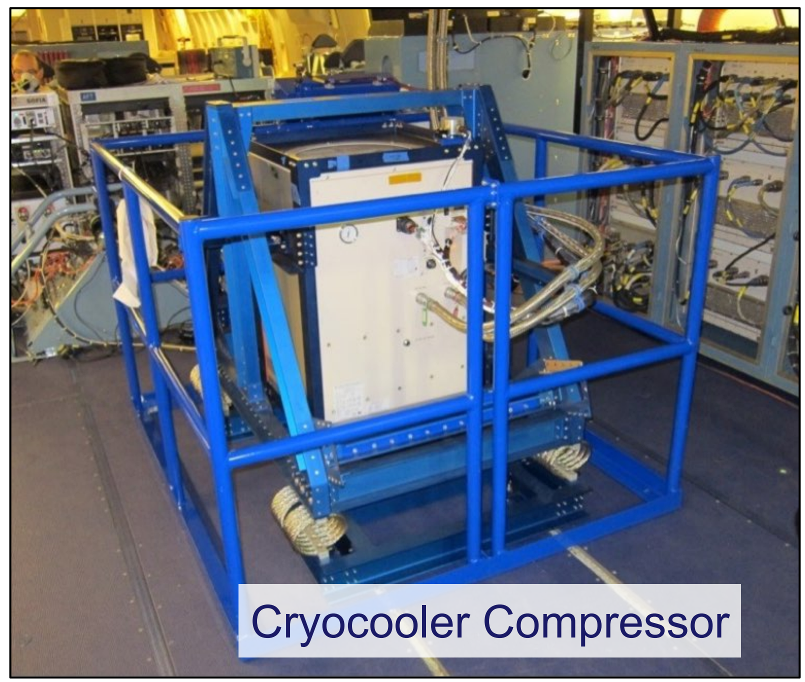
Government Furnished Equipment (GFE) [4.3] [cont.]

Telescope Assembly Alignment Simulator (TAAS)



Auxiliary “AUX” Rack

Roughing & Turbo Vacuum Pumps



Cryocooler Compressor

SOFIA Science Instrument System Specification SE01-2028 [5.1]

- **Section 5.1** introduces the ***SOFIA Science Instrument System Specification*** (SOF-AR-SPE-SE01-2028) and its relation to other SOFIA system specifications within the ***SOFIA Specification/ Product Tree*** (SOF-DF-SPE-SE01-068).
- The "2028" spec contains the verifiable system requirements that all SI must meet, and includes airworthiness, quality assurance, mission assurance, and safety requirements.

- Details about the SOFIA Science Instrument System Specification will be provided in a presentation to follow by:
  - **Stefan Rosner,** Science Instrument Engineer

Top-Level Science and Technical Performance Requirements [5.2]

- ***Section 5.2*** provides a brief description of the ***Top-Level Science and Technical Requirements*** which the Instrument Developer will define.
- Instrument selection proposals include a list of performance requirements the instrument needs to achieve in order to the execute the scientific objectives of a proposed investigation.
- The final top-level science and technical performance requirements will be negotiated with the SOFIA Program before this set of requirements is baselined.
- The *NASA SOFIA Science Instruments Developer Manager* is the NASA Compliance Authority who approves the Instrument Developer's V&V approach for verifying the top-level science and technical performance requirements, and determining if verification results satisfy the requirements.

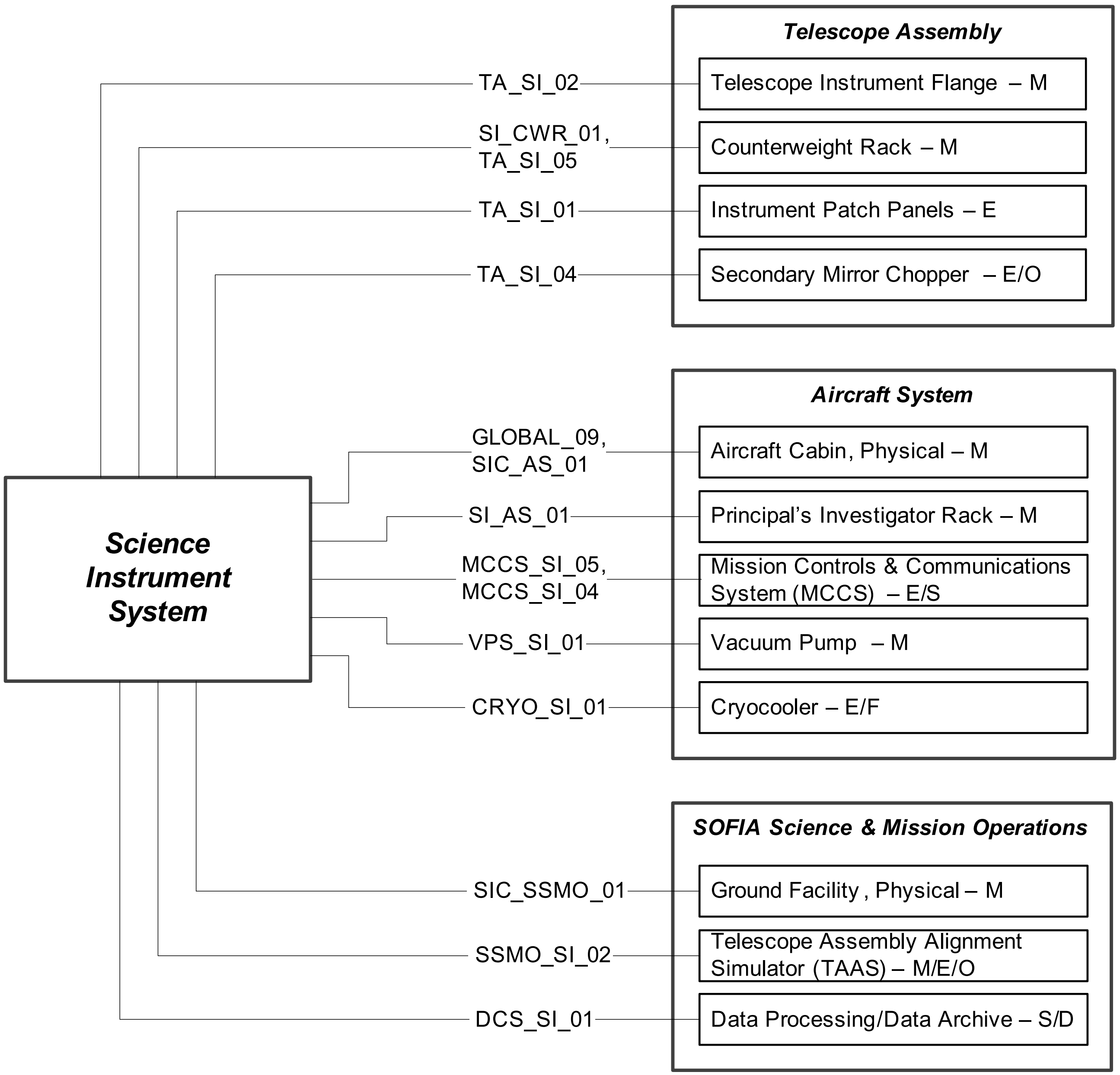
Interfaces [5.3.1]

IDHB Table 5.3.1-1: Table describing science instrument interface control documents

ICD Designator	Document Number	ICD Title	Scope
GLOBAL_09	SOF-DA-ICD-SE03-002	Science Instrument Envelope	The instrument dynamic, static, and installation spatial envelopes
TA_SI_01	SOF-DA-ICD-SE03-036	Cable Load Alleviator Device/Science Instrument Cable Interface	TA patch panel electrical interfaces to the counterweight rack and instrument assembly
TA_SI_02	SOF-DA-ICD-SE03-037	Telescope Assembly/Science Instrument Mounting Interface	Mechanical interface between the instrument assembly and the telescope flange
TA_SI_04	SOF-DA-ICD-SE03-038	TA Chopper Processor/Principal Investigator Computer Direct Analog Interface	Analog and TTL trigger interface between the instrument and chopper
TA_SI_05	SOF-DA-ICD-SE03-051	SI Equipment Rack/TA Counterweight Interface	Mechanical interface between the counterweight rack and the TA
SI_CWR_01	SCI-AR-ICD-SE03-2027	SI Equipment to Counterweight Rack	Requirements for installed equipment in the counterweight rack
SI_AS_01	SOF-DF-ICD-SE03-2015	Principal Investigator Equipment to PI Rack to Aircraft System	Requirements for installed equipment in the PI hardware racks
MCCS_SI_05	SOF-AR-ICD-SE03-2029	PI Patch Panel to PI Equipment Rack(s)	PI patch panel electrical connections to PI racks
MCCS_SI_04	SOF-DA-ICD-SE03-052	MCCS to SI Software Interface (Functional)	Commands and syntax for instrument software command to the observatory control software
DCS_SI_01	SCI-US-ICD-SE03-2023	Data Cycle System to Science Instrument	Defines data file interface for instrument data archived by the Data Cycle System
VPS_SI_01	SOF-DA-ICD-SE03-2022	SI to Aircraft Vacuum Pump	Interface to on-aircraft vacuum pump system (LHe pumping and other uses)
SIC_AS_01	SOF-AR-ICD-SE03-205	SI Handling Cart to Aircraft System	Requirements on the instrument installation cart to ensure safe transportation onto and through the aircraft
SIC_SSMO_01	SCI-AR-ICD-SE03-2017	SI Handling Cart to SSMO Facility Interface	Ground facility constraints on instrument lab carts and stands
SSMO_SI_02	SCI-AR-ICD-SE03-2020	Telescope Assembly Alignment Simulator (TAAS)/Science Instrument (SI) ICD	Interfaces between instrument and the telescope assembly alignment simulator
CRYO_SI_01	APP-DA-ICD-SE03-2059	Cryocooler System to Science Instrument (SI) ICD	Defines the electrical power, electronic signaling, and fluidic interfaces

Interfaces [5.3.1] [cont.]

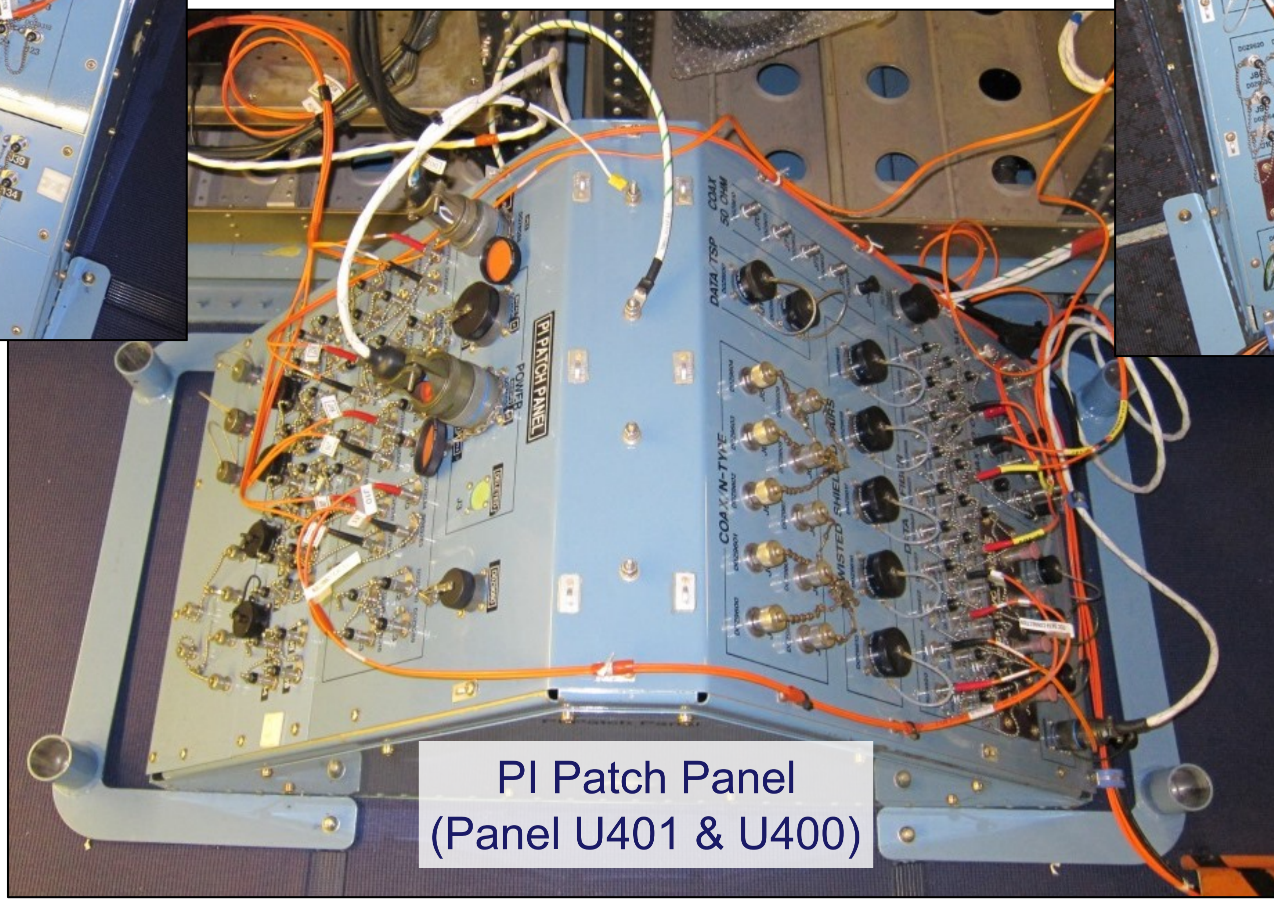
IDHB Figure 5.3.1-1: Science Instrument interface block diagram



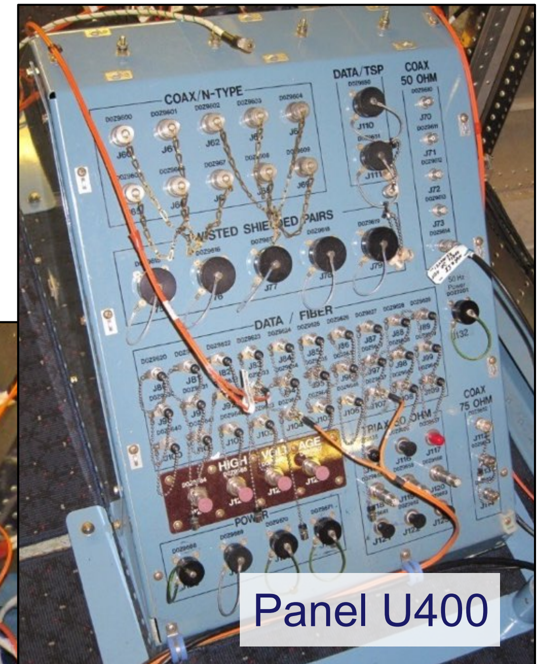
Interface Abbreviations
M = Mechanical
E = Electrical
F = Fluidic
O = Optical
S = Software
D = Data

Interfaces [5.3.1] [cont.]

Panel U401



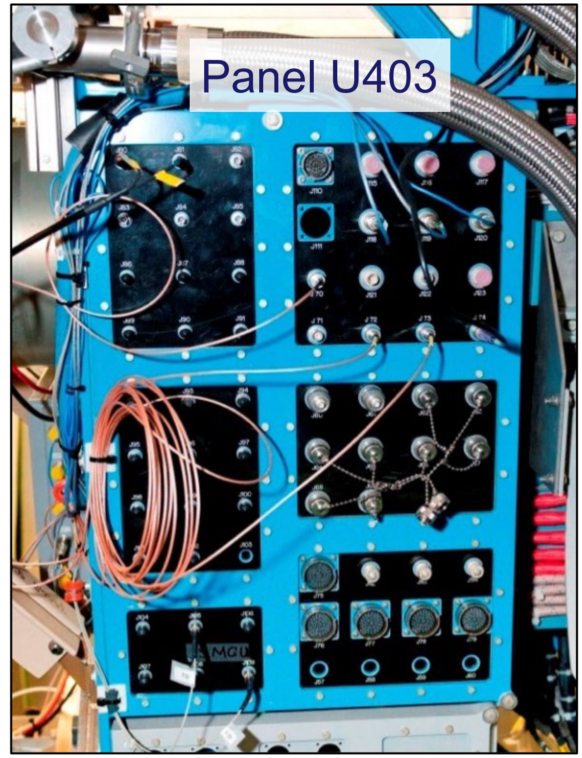
PI Patch Panel
(Panel U401 & U400)



Panel U400

Interfaces [5.3.1] [cont.]


Panel U402


Panel U403

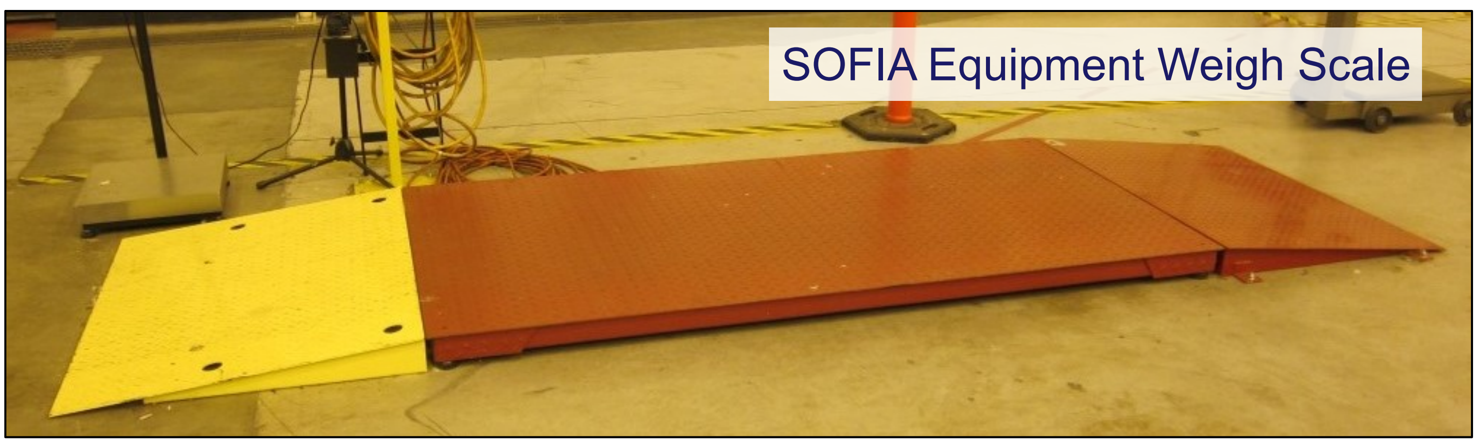

Panel U404 (He QD Panel)


Chopper Junction Box

Interfaces [5.3.1] [cont.]

Equipment Loading Truck Liftgate (used at AFRC B703)

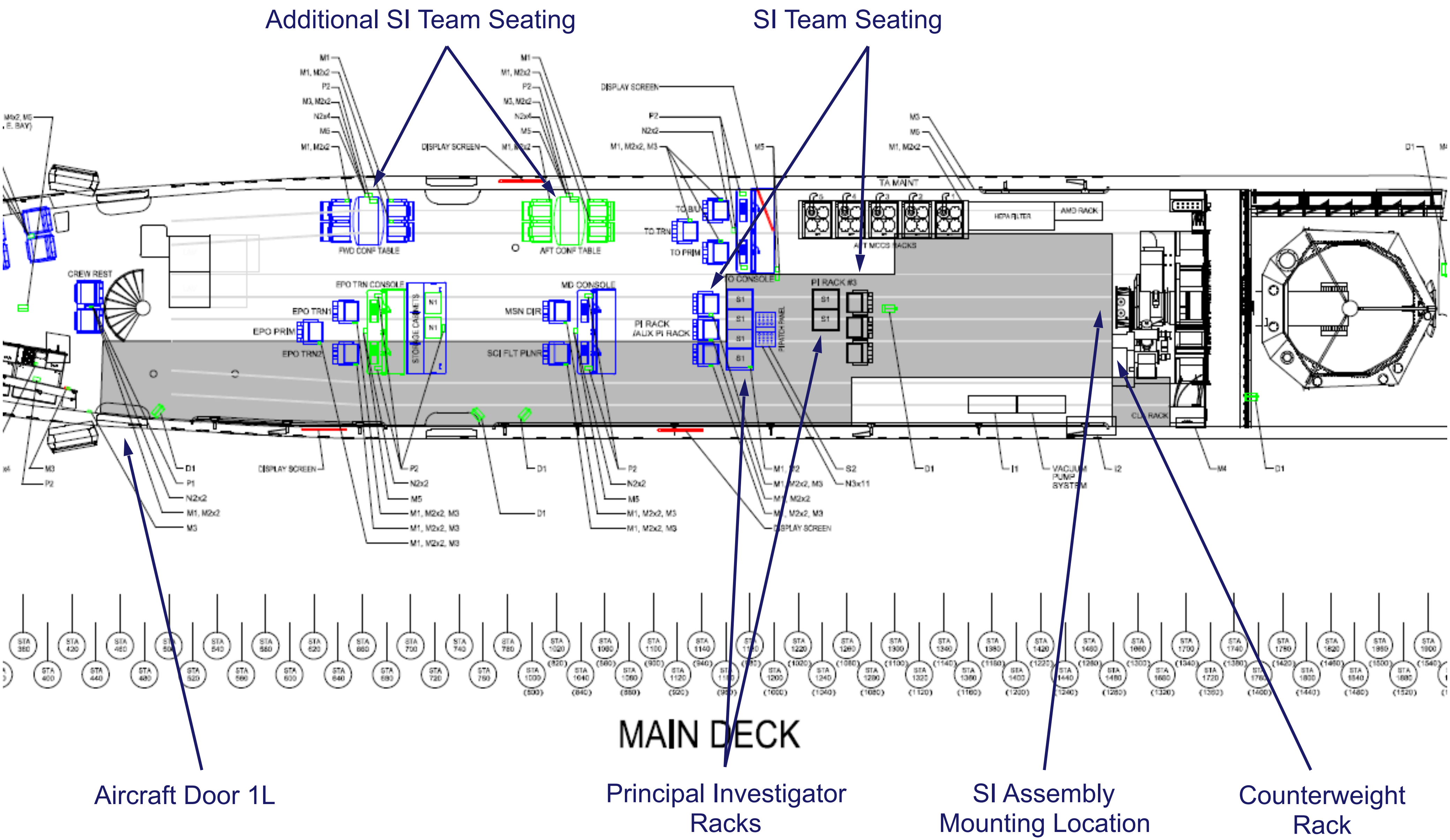
Equipment Loading Platform (used on NZ Deployment)



SOFIA Equipment Weigh Scale

Layout of Personnel Accommodations (LOPA) [6.2.10]

Graphic is from APP-DF-DWG-SE02-2924

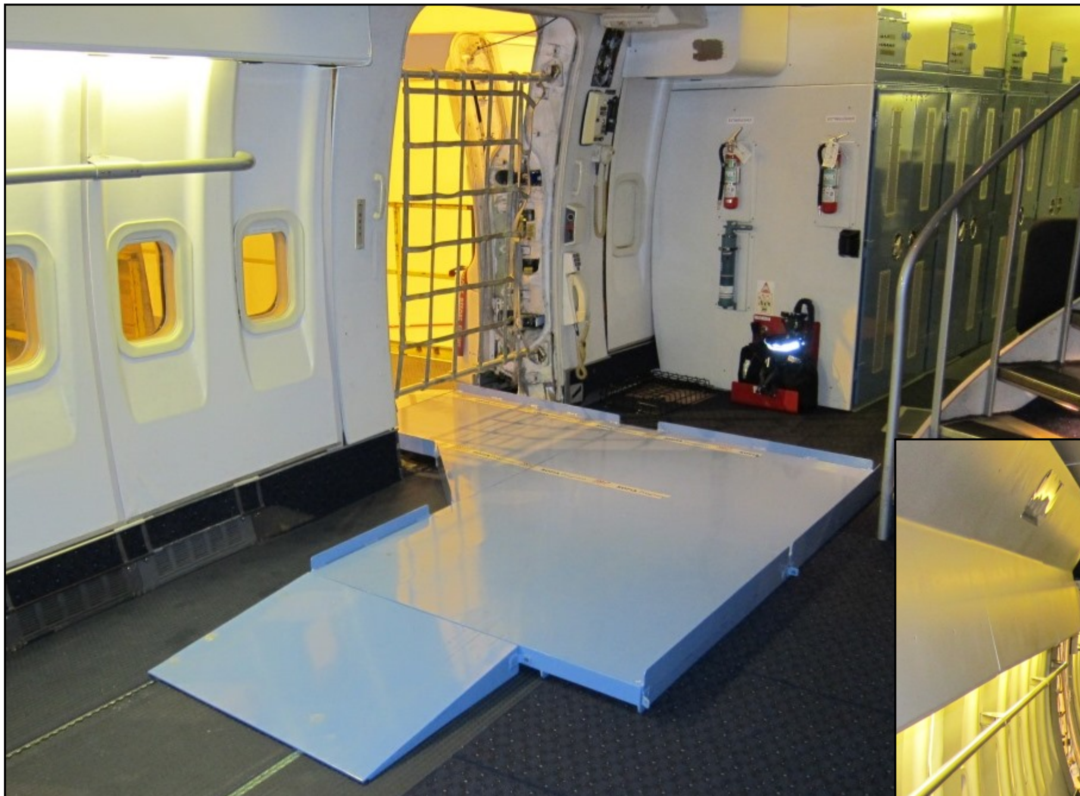


LOPA [6.2.10] [cont.]

Instrument Loading to
Aircraft Door 1L via
Equipment Loading Truck

Aircraft Door 1L Entry for
Science Instrument and Racks

LOPA [6.2.10] [cont.]

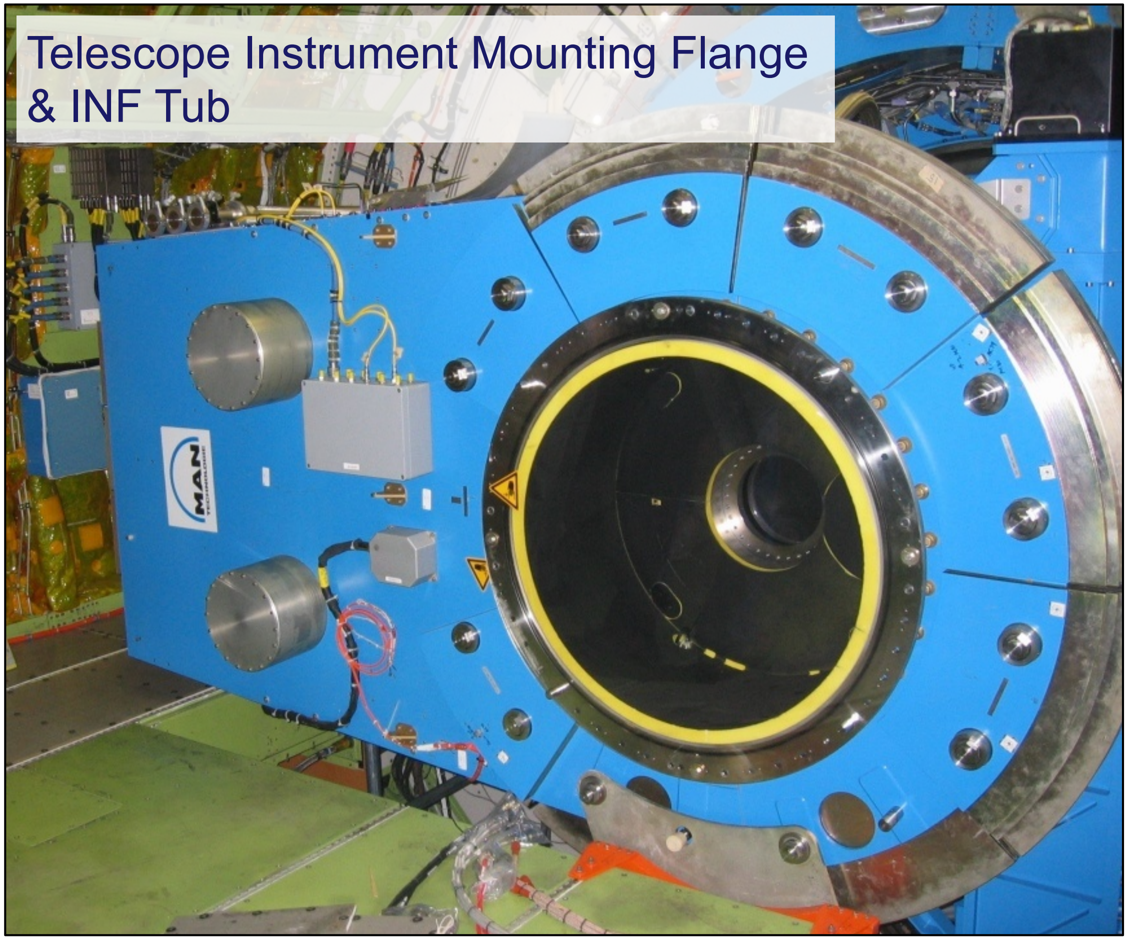


Aircraft Door 1L Entry (Cabin-side)

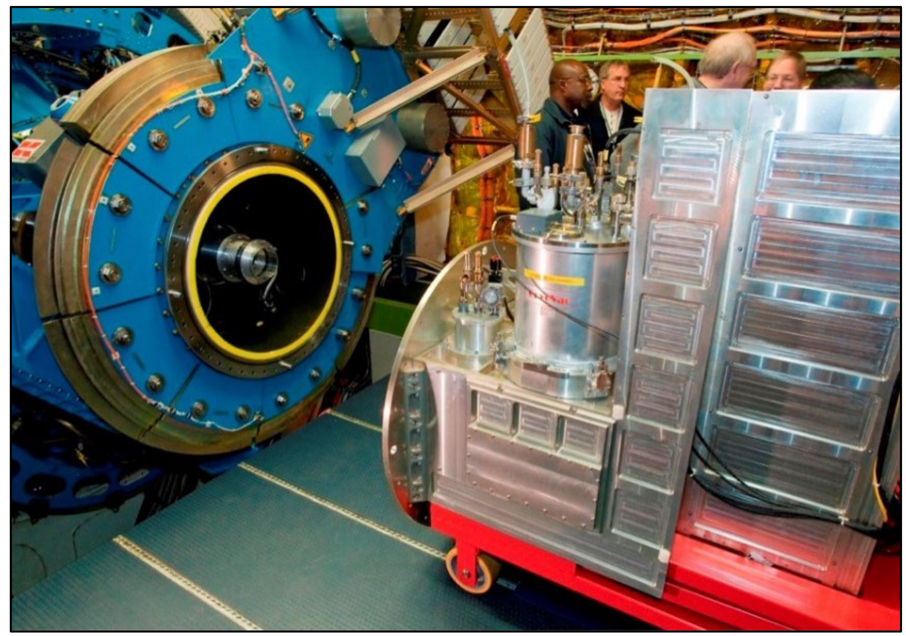
Note: The Equipment Loading Ramp in this photograph is an old design; the current ramp is wider

SI Cart/Equipment Transport Path,
SI Team Seating, PI Racks,
& PI Patch Panel

LOPA [6.2.10] [cont.]

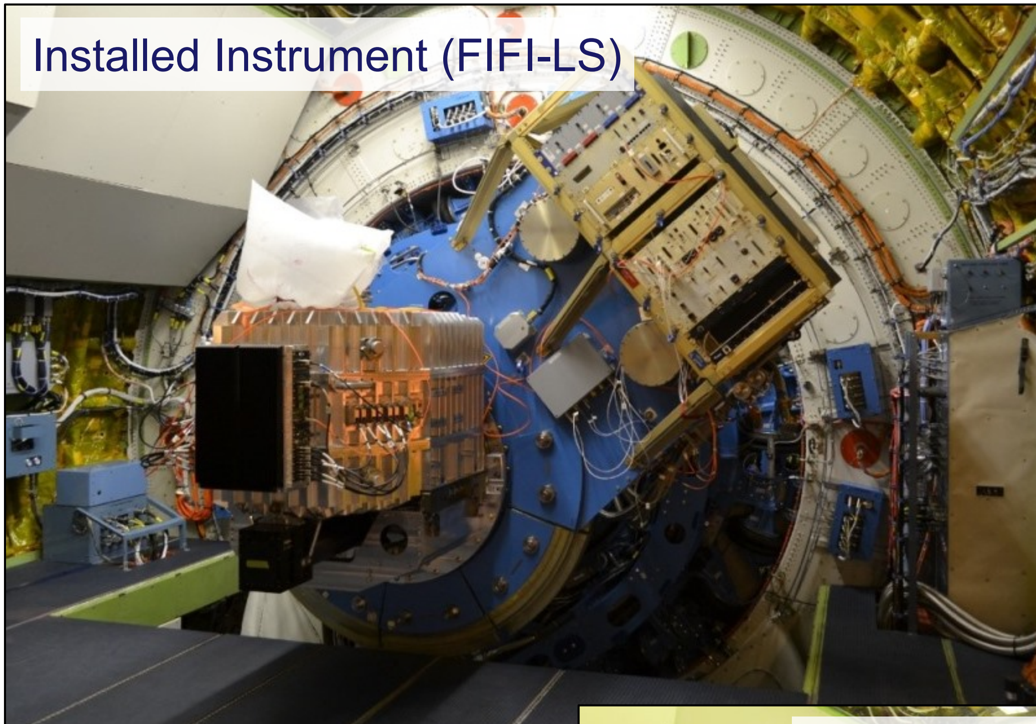


Telescope Instrument Mounting Flange & INF Tub

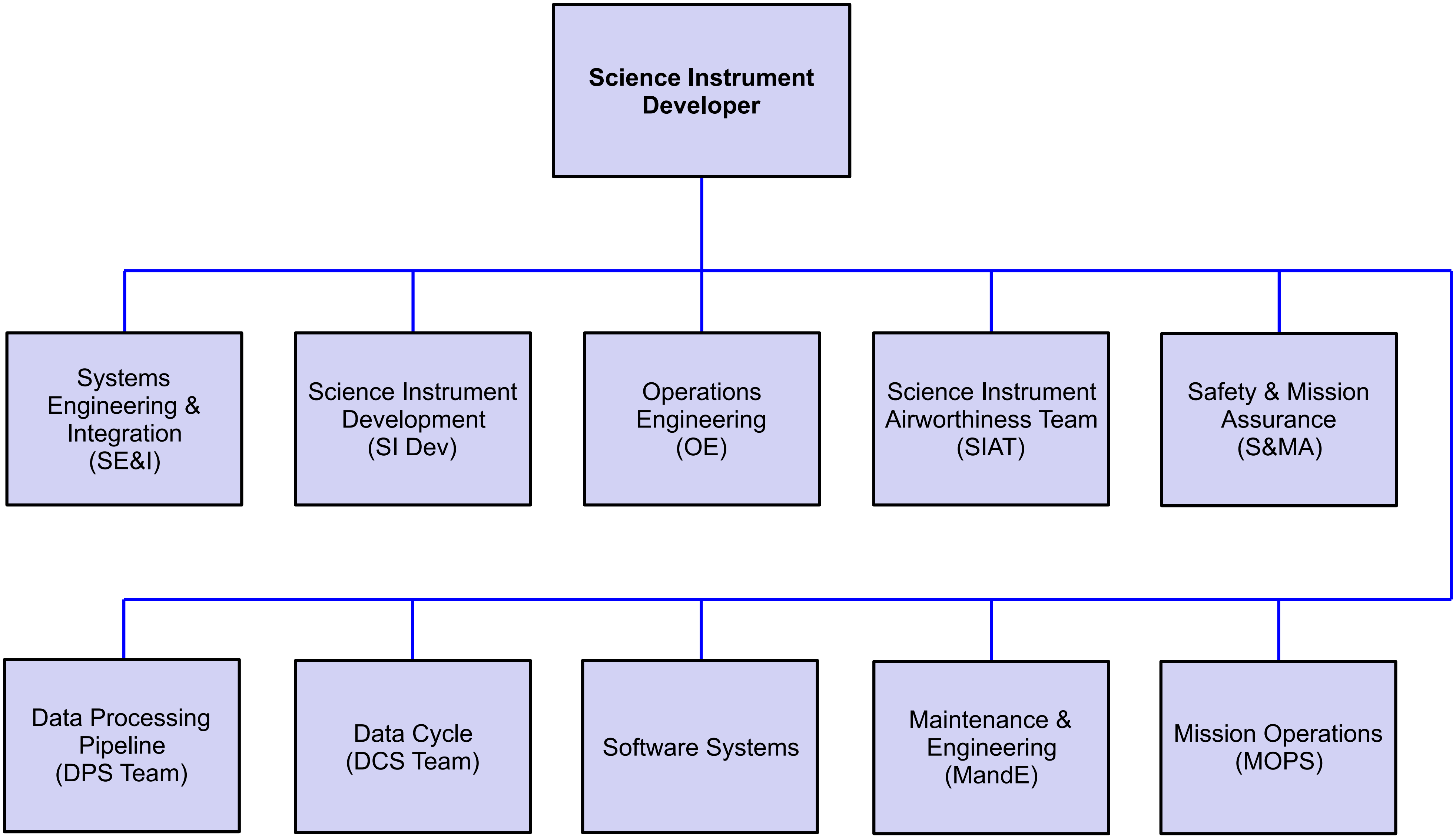


Installing an Instrument Assembly

LOPA [6.2.10] [cont.]



SOFIA Technical Groups [12]



Verification [5.4]

- ***Section 5.4*** introduces *Verification & Validation;* providing an overview of the verification process and the role the Instrument Developer will play in the planning and execution of verification activities to show compliance with requirements.
- The development phase in which verification will be conducted, and the verification method and activity to be performed, will depend on the specific requirement. Verification close-out for a requirement will occur in the last phase that verification is required.
- Verification activities include:
  - Testing used to assist in the development and maturation of products, product elements, or manufacturing or support processes
  - Engineering-type testing, analysis, inspection, or demonstration used to verify the status of technical progress, verify that design risks are minimized, substantiate achievement of technical performance, and certify readiness for initial validation testing. (Instrument validation will primarily occur during the commissioning flights.)

Verification [5.4] [cont.]

- ***Section 5.4.4*** describes the options available to the Instrument Developer when noncompliance with a requirement is encountered during development.
  - When noncompliance is identified during the design phase (before hardware fabrication or software coding has begun), Instrument Developers are strongly encouraged to explore design alternatives that would bring the instrument into compliance with the requirement.
  - The SOFIA Program has a formal process for reviewing and granting deviations and waivers, thereby relieving an instrument against a specific requirement, if the impact assessment and justification provided by the Instrument Developer in a *Request for Deviation or Waiver* (RDW) are determined to be acceptable by the Program.
  - A *deviation* request is for noncompliance identified in the design phase. A *waiver* request is for noncompliance identified during the implementation phase (e.g., hardware fabricated, software coded)

Verification [5.4] [cont.]

- ***Section 5.4.5*** describes the typical verification activities that are conducted prior to each Instrument Project milestone/technical review (e.g., PDR, CDR, Pre-Shipment Review, Pre-Installation Review). Highlights from these subsections are provided in the next few charts.

- ***PDR Verification Activities*** [5.4.5.1]
  - Instrument Developer delivers draft documents and analyses based on the preliminary design of the instrument, for review by NASA to assess instrument compliance with requirements.
  - Examples of verification activities performed for PDR include analysis of: instrument mass & c.g., cryostat vent pressure system, power budgets, physical/spatial envelopes).
  - The majority of design documentation will be delivered in the next phase of development (CDR)

Verification [5.4] [cont.]

- ***CDR Verification Activities*** [5.4.5.2]
  - Instrument Developer delivers updated and new documentation based on the detailed design of the instrument, for review by NASA to assess instrument compliance with requirements.
  - Examples of verification activities performed for CDR include analysis of: instrument assembly drawings, rack configuration drawings, instrument mass & c.g., cryostat and vent system pressure stress analysis, power consumption, physical/spatial envelopes, cart design, FITS data file header definition, and data reduction pipeline design.
  - In this critical design phase, the Instrument Developer will submit deviation requests to the SOFIA Program for all noncompliances of the instrument with SOFIA requirements, that are identified before and during CDR verification, before proceeding to build the instrument (e.g., procuring materials, fabricating parts, coding software).

Verification [5.4] [cont.]

- ***Pre-Ship Verification Activities*** [5.4.5.3]
  – Whereas in earlier development phases analysis was the primary method of verification, verification methods for activities performed before shipment will also include inspection, demonstration, and test.
  – Instrument Developer delivers any needed update or revision to any earlier design documentation (e.g., drawings, analyses) to reflect the as-built instrument system.
  – This section contains subsections which further describe the verification activity types and the SOFIA Technical Groups which the Instrument Developer will interact with to conduct verification:
    - Airworthiness Inspections
    - SE&I Verification (Non-Software)
    - Instrument Software-MCCS Testing
    - Instrument Data Product-DCS Testing
    - Instrument Data Reduction Pipeline-DPS Testing

Verification [5.4] [cont.]

- ***Pre-Install Verification Activities*** [5.4.5.4]
  - Instrument testing and characterization on the Telescope Alignment Simulator (TAAS)
  - Software testing in a System Integration Lab (SIL)
  - Any verification activities which are required before instrument installation on the aircraft
- ***EMI Test*** [5.4.5.5]
  - Electromagnetic interference and electromagnetic compatibility (EMI/EMC) test is conducted with the instrument installed on the aircraft on the ground, before the first flight
- ***Line Operations*** [5.4.5.6]
  - To demonstrate instrument operation and execute observing scenarios on the ground before performing the operations in flight

Verification [5.4] [cont.]

- ***Δ Delta verification*** [5.4.5.8]
  - After completing CDR, any design change that may impact instrument compliance with a baselined requirement—either SOFIA requirement or instrument performance requirement—must be communicated to the appropriate NASA Compliance Authority before the change is made, in order for NASA to assess the impact and to determine if any delta verification will be required.
  - This also applies after the instrument is built; modifications or upgrades to instruments will require a delta verification assessment by NASA, followed by any needed delta verification activities, to confirm the instrument configuration remains in compliance with requirements.

- ***SOFIA Science Instrument System Specification and ICD Requirements Verification Matrix Template*** (SOF-NASA-REP-SV05-2057):
  - The Requirements Verification Matrix Template ("RVMT") provides guidance information for the verification activities expected to be conducted to show compliance of an instrument with the SOFIA requirements.
  - The RVMT contains the requirements defined in the SE01-2028 SI System Specification and SOFIA ICDs; the RVMT does not define any new requirements.
  - RVMT identifies the expected verification method(s) and phase(s) for each requirement, and provides a description of the typical verification activities conducted at each applicable development phase.
  - This template is used by NASA and the Instrument Developer to form the specific "SE01-2028 SI System Specification & SOFIA ICDs" requirements verification matrix for the instrument.

SOFIA SI Requirements Verification Matrix Template [5.4.3.1] [cont.]

- The RVMT identifies the NASA Compliance Authority for each requirement, i.e. *SE&I* (SOFIA Systems Engineering & Integration) or *SIAT* (SOFIA Science Instrument Airworthiness Team)
- A set of columns is provided for the Instrument Developer to self-identify instrument compliance with each requirement, and a field to record the verification result and compliance artifact.
- The RVMT contains another set of columns that is used by NASA to identify instrument compliance based on the results of verification performed in each development phase.
- The Instrument Developer is responsible for delivering an updated RVM to NASA before each of the Instrument Project milestone/technical reviews (i.e., PDR, CDR, Pre-Ship Review, Pre-Install Review), and final delivery of this RVM before the Acceptance Review)

SOFIA SI Requirements Verification Matrix Template [5.4.3.1] [cont.]

Document number

Paragraph Identification Number

Requirement Text

Verification Method(s) by Development Phase

Verification Activity Description

Document	Paragraph Identification (ParID)	Requirement	Verification Method by Development Phase					Verification Activity Description	Compliance / Artifacts	SI Status (Verification status to be filled out by SI Team)					NASA Compliance Authority	NASA Status (Verification status to be filled out by NASA)				
			PDR	CDR	Pre-Ship	At AFRC prior to installation	Installation and checkout			PDR	CDR	Pre-Ship	At AFRC prior to installation	Installation and checkout		PDR	CDR	Pre-Ship	At AFRC prior to installation	Installation and checkout
SE01-2028 Rev. B	3.5.2.9	Screws, nuts, bolts or other threaded fasteners that are part of a Science Instrument flight hardware structural load path for design characteristics classified as Critical and are needed to maintain positive Margins of Safety (MS) shall use self-retaining or self-locking features.	N/A	I	I	I	I	(CDR) SI developer to prepare assembly drawings within the Airworthiness Data Package presented at CDR for review (Inspection) by SE&I and SIAT to show how all screws, bolts, nuts or other fasteners that are part of an SI flight H/W structural load path for design characteristics classified as Critical and are needed to maintain positive MS, use one of the preferred self-retaining / self-locking features (or where use of such preferred fasteners are deemed impractical, present an alternative for review and concurrence by the SIAT). (Pre-Ship ~ Installation and checkout, as scheduled) SI developer to support SIAT physical inspections via site visits at SI development institution / facility (Pre-ship), within the Preflight Integration Facility (PIF) or SI Labs at AFRC B703 prior to installation, and after Installation on SOFIA to confirm as-built SI compliance with approved baseline assembly drawings.							SIAT					

Compliance / Artifacts

SI Status

NASA Compliance Authority

NASA Status

<u>Verification Methods</u>

- ❑ Analysis
- ❑ Inspection
- ❑ Demonstration
- ❑ Test

<u>Development Phases</u>

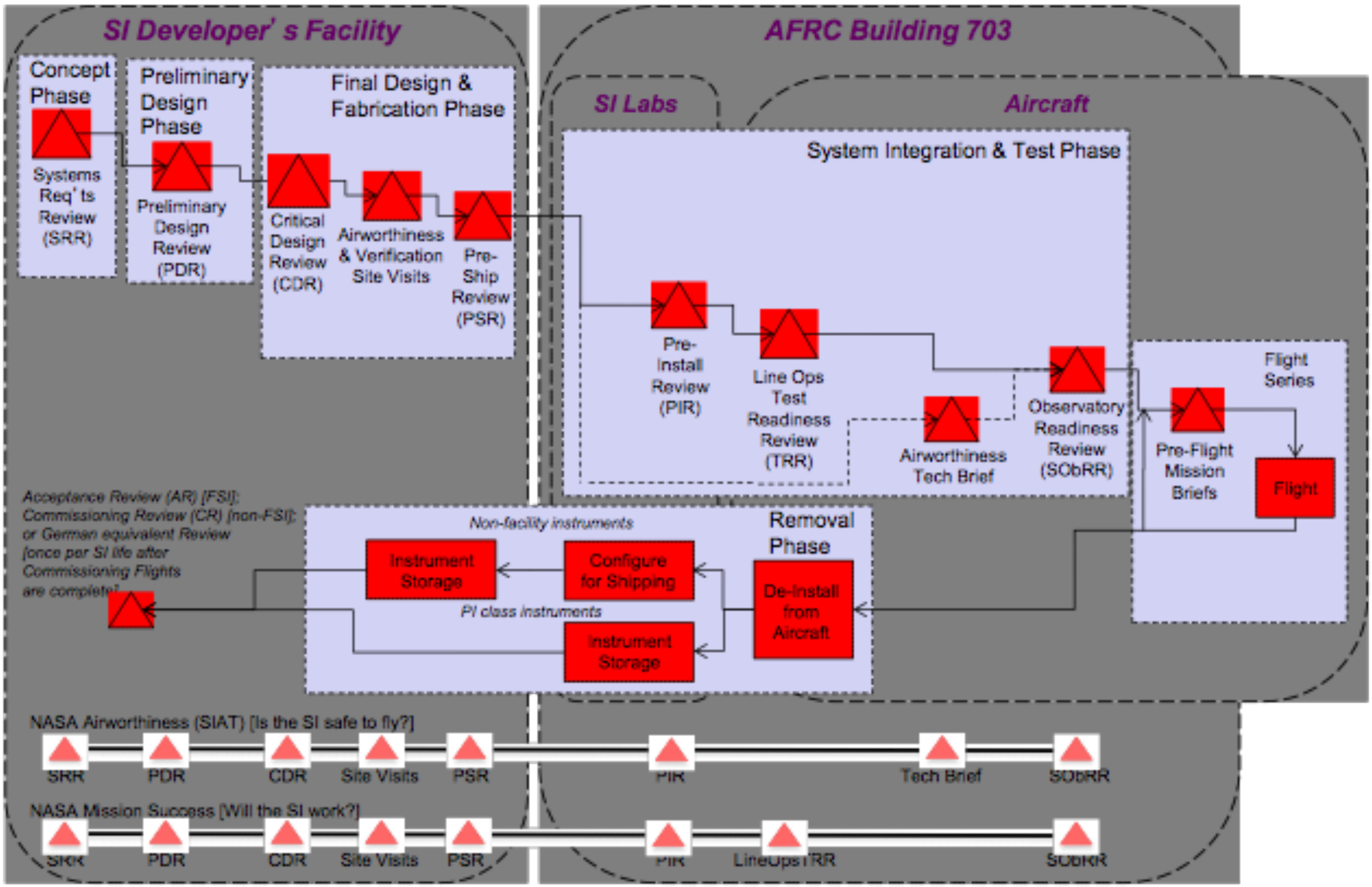
- ✓ PDR
- ✓ CDR
- ✓ Pre-Ship
- ✓ At AFRC Prior to Installation
- ✓ Installation and Checkout

Observatory Facilities [6.2]

- ***Section 6.2*** describes a number of Observatory Facilities that pertain to science instruments, including:
  - Science Instrument Labs at AFRC B703
  - Pre-Flight Integration Facility (PIF)
  - Systems Integration Laboratory (SIL)
  - Secondary mirror buttons
  - Vacuum pump system
  - Cryocooler system

- Details about these Observatory Facilities will be provided in presentations to follow by:
  - **Stefan Rosner,** Science Instrument Engineer
  - **Elizabeth Moore,** Information Systems Dev. Manager
  - **Bill Wohler**, SI Software Interface Lead
  - **Zaheer Ali,** Science Instrument Lab Supervisor

Instrument Development Reviews [7.3]



Instrument Development Reviews [cont.]

- The IDHB contains detailed descriptions of each Technical Review, including the Entrance & Success Criteria and deliverables due at each review.
  - High-level summaries of the reviews are provided below

- ***System Requirements Review (SRR)*** [7.4.1]
  - ***Objective***: Instrument Developer demonstrates understanding of all system / interface / instrument performance requirements, provides draft of complete set of instrument performance requirements for baseline approval, provides mature drafts of programmatic and system development plans, and is ready to begin preliminary design of the instrument.
  - ***Upon successful completion of the review***: SOFIA Program approves Instrument Developer to proceed with preliminary design of the instrument.

Instrument Development Reviews [cont.]

- ***Preliminary Design Review (PDR)*** [7.5.1]
  - ***Objective***: Instrument Developer demonstrates that the preliminary design of the instrument will meet system / interface / instrument performance requirements, documentation deliverables have been delivered, all PDR verification activities have been completed, project risks have been identified, and Instrument Developer is ready to being detailed design of the instrument.
  - ***Upon successful completion of the review***: SOFIA Program approves Instrument Developer to proceed with detailed design of the instrument.

- ***Critical Design Review (CDR)*** [7.6.1]
  - ***Objective***: Instrument Developer demonstrates that the mature design of the instrument meets system / interface / instrument performance requirements, documentation deliverables have been delivered, all CDR verification activities have been completed, approved deviations have been obtained or deviation requests have been drafted and submitted to the SOFIA Program, project risks have been identified, and the Instrument Developer is ready to begin full-scale fabrication of the instrument.
  - ***Upon successful completion of the review***: SOFIA Program approves Instrument Developer to proceed with full-scale fabrication of the instrument.

Instrument Development Reviews [cont.]

- ***Pre-Shipment Review (PSR)*** [7.6.2]
  - ***Objective***: Instrument Developer demonstrates that the necessary instrument tests at the developer's institution have been completed and test results satisfactorily meet the established requirements, documentation deliverables have been delivered, all pre-ship verification activities have been completed, approved waivers have either been obtained or waiver requests have been submitted to the SOFIA Program for disposition, project risks have been identified, and the instrument is ready for shipment.
  - ***Upon successful completion of the review***: SOFIA Program approves Instrument Developer to proceed with instrument shipment to AFRC B703.

- ***Pre-Installation Review (PIR)*** [7.7.1]
  - ***Objective***: Instrument Developer demonstrates that the necessary instrument tests in the SI Labs at AFRC B703 have been completed and test results satisfactorily meet the established requirements, updated documentation has been delivered, all pre-installation verification activities have been completed, project risks have been identified, approved waivers have been obtained, and instrument is ready for installation.
  - ***Upon successful completion of the review***: SOFIA Program approves Instrument Developer to proceed with instrument installation and integration activities on the Observatory.

Instrument Development Reviews [cont.]

- ***Acceptance Review (AR)*** [7.7.4]
  - ***Objective***: Instrument Developer demonstrates instrument performance requirements have been verified using data collected during commissioning, any new waivers have been obtained, all remaining required deliverables are ready for delivery, and the Instrument Developer is ready to transfer ownership of the instrument to the NASA.
  - ***Upon successful completion of the review***: NASA begins the instrument Acceptance Process, in which the *Material Inspection and Receiving Report* (DD-250) is signed, and concludes with NASA formally taking ownership of the instrument.

Airworthiness Process [8]

- ***Section 8*** describes the SOFIA Airworthiness Certification Process for Science Instruments; content highlights include:
  - Role and responsibilities of the Science Instrument Airworthiness Team (SIAT)
  - Description of the Flight Readiness Review and Airworthiness and Flight Safety Review Board (AFSRB)
  - Technical topics including system safety, structural load analysis, pressure vessels, electrical systems, radiation, cryogens, and software airworthiness

- Details about the SI Airworthiness Certification Process and SI airworthiness deliverables will be provided in presentations to follow by:
  - **Maureen Savage,** USRA SI Development Manager
  - **Tim Krall,** NASA SIAT Chair

Instrument Change Control [9]

- ***Section 9*** covers topics pertaining to instrument and document change control.

- ***Science Instrument Configuration Change Request*** [9.1]
  – Once the configuration of the instrument has been verified by SIAT, the Instrument Developer will submit a science instrument configuration change request (SICCR) for review and approval by the SOFIA Program for any proposed configuration change which affects airworthiness, before the change is made
- ***Instrument Log Notebook*** [9.2]
  – Once the configuration of the instrument has been verified by SIAT, the Instrument Developer will record any changes made to the instrument in a notebook, available for review by SIAT, to ensure the changes do not have any unintended impact on airworthiness of the instrument.

Instrument Change Control [9] [cont.]

- ***Instrument Configuration Sheet*** [9.3]
  – Prior to each installation on the aircraft, the Instrument Developer will provide a configuration sheet to the SOFIA Program, identifying the hardware and software configuration of the instrument. The information documented in the configuration sheet typically includes the configuration of configurable/adjustable elements, the specific operational mode(s) to be used, or any other elements of the instrument that may change between flight series.
- ***Document Configuration Management*** [9.4]
  – Implemented by Instrument Developer to ensure there are no differences between the configuration of the "as-built" instrument and the configuration defined in design documents.
  – Implementing a document change control process, including establishing a document numbering and revision/version designation system

Environmental and Design Guidelines [10]

- ***Section 10*** provides general information about the environmental conditions of the cabin environment inside the aircraft and also the environment mounted to the telescope.
  - Temperature and Humidity
  - Pressure
  - Arcing and Coronal Discharge
  - Nasmyth Tube environmental conditions
  - Vibration
  - Electromagnetic Interference / Compatibility

Safety & Mission Assurance [11]

IDHB Figure 11-1: S&MA Responsibilities

SI Developer's Facility

SOFIA S&MA
- Assists NASA to create/mod contract
- Works with SE&I & SIAT to verify req'ts listed in Verification Plan or in SI System Spec
- Reviews S&MA-related plans & ADP
- Coordinates Gov't Mandatory Inspection Points (GMIPs) with contractor/grantee
- Witnesses GMIPs
- Coordinates items with AFRC B703 Facility Safety which would impact B703 Safety
- PDR, CDR, Pre-Ship Review member
- Participate in site visits, if requested
- Monitors and audits contractor/grantee's QA process
- Works with SI team to get SI Hazard Reports (HRs) approved by SSWG

SIAT
- Reviews SI airworthiness documentation
- Participates in Airworthiness site visits
- Provides SI airworthiness certification
- Verify req' ts listed in Verification Plan & SI System Spec as SIAT-verified
- PDR, CDR, & Pre-Ship Review member
- Gov' t QA oversight/witness for design characteristics classified Safety Critical

AFRC Building 703

SI Labs

SOFIA S&MA
- S&MA sign-off authority on procedures
- Primary QA stamp-off authority on work
- Approves procedure redlines

SIAT
- Verify req'ts listed in Verification Plan & SI System Spec as SIAT-verified

Aircraft

SOFIA S&MA
- S&MA sign-off authority on all procedures
- QI/QA stamp-off on work
- Mishap Response
- Lead for aircraft hazards (SSWG)
- Monitor hazardous operations

SOFIA S&MA
- Impound items and assist AFRC/ ARC during a Mishap Response

AFRC B703 Facility Safety
- Reviews safety-related procedures
- Audit facility for safety

Safety & Mission Assurance [11] [cont.]

- ***Risk-tailored Assurance Approach*** [11.1]
  - Identifies the design characteristics of Science Instruments that are classified as *Safety Critical* by the SOFIA Program, and the additional change controls required for these items.
- ***Quality Planning*** [11.2]
  - Describes the content that should be included in the Instrument Developer's Quality Plan.
- ***Procurement Control*** [11.4]
  - Provides guidance on supplier selection, procurement documents, source inspection/supplier surveillance, receiving inspection, and conformity records for procured articles.
- ***Identification Control*** [11.5]
  - Provides guidance on implementing an identification scheme for articles and materials (e.g., part / serial / lot numbers), article labeling, and creating and maintaining an identification list for SI and COTS articles.

Safety & Mission Assurance [11] [cont.]

- ***Fabrication Control*** [11.6]
  - Describes the role of the SI Team in overseeing production operations to ensure as-built articles conform to all specified requirements in engineering drawings and specifications in accordance with the institution procedures and best practices as determined by the team.
- ***Inspection and Test*** [11.7]
  - Describes role of SI Team QA Lead in determining appropriate inspection points and in-process test points during fabrication and assembly to verify conformity to drawings and requirements, and that no workmanship issues exist.
- ***Software Assurance*** [11.10]
  - Identifies the software deliverables typically required to support software assurance. Provides references to SOFIA software documents that provide guidance on SI software development, and describe SI software within the context of the overall SOFIA Program.

Safety & Mission Assurance [11] [cont.]

- ***System Safety*** [11.14]
  - Describes the process for which hazards are identified and evaluated throughout the development process of the Science Instrument. References the four generic SI hazards and associated hazard report templates. Defines the hazard severity and probability classifications.
- ***Government Surveillance*** [11.15]
  - Describes the role of NASA S&MA in reviewing the quality practices implemented at the Instrument Developer's site, including inspection of the instrument Quality Plan, operating plans and procedures, quality practices (e.g., procurement, control of materials, configuration management), qualification of key in-house fabrication and non-destructive examination (NDE) processes, conformity records, and witnessing key inspections and tests.

Deliverables [Appendix A.1]

- ***Appendix A.1 Deliverable Items List*** are the typical hardware, software, and documentation deliverables which will appear in a Statement of Work
  - 71 items total (IDHB lists 73 items; 2 of which are specific to PI-class instruments)
  - Instrument Developer does not necessarily need to deliver a separate document for each of the identified deliverables (e.g., separate documents for instrument control software manual and Operating manual vs. a single document containing both)
    - *The itemization scheme of deliverables presented in Appendix A.1 and A.2 is a recommendation, which may additionally facilitate with configuration management of these work products by the Instrument Developer during development; however it is at discretion of the Instrument Developer of how particular work products/deliverables will be released as documents as long as it communicated to the SOFIA Program and easily understood which deliverables are contained within which document.*

Deliverables [Appendix A.1] [cont.]

- The deliverable items listed in ***Appendix A.1*** are the following:
  - ***Hardware***
    - Complete science instrument assembly
    - Electronics, equipment, and cables to be mounted in up to three PI racks
    - Electronics, equipment, and cables to be mounted in up to one counterweight rack
    - Interconnect cables between the counterweight rack and the instrument assembly, and the rack and the instrument to the Observatory patch panels
    - Any science instrument specific test equipment needed to calibrate and maintain the instrument
    - Instrument installation cart
    - Any instrument turnover carts or test stand(s) needed to maintain the instrument
  - ***Software***
    - Spare hardware for items with limited life or risk of failure as determined by the instrument risk management program
    - Instrument control software
    - Software and test scripts required to calibrate or maintain the instrument
    - Instrument data analysis/pipeline software

Deliverables [Appendix A.1] [cont.]

- ***Programmatic Documents***
  - Project Management Plan
  - Schedule
  - Monthly status reports
  - Yearly funding requirements estimates
- ***Requirements Documents***
  - Instrument science and technical performance requirements
  - Instrument science and technical performance verification matrix
  - Instrument SI System Specification and ICD requirements verification matrix
- ***Airworthiness Documents***
  - Drawing package
  - Quality plan
  - Electrical systems report
  - Instrument assembly structural analysis report
  - Counterweight rack report
  - PI rack report
  - System safety assessment
  - Pressure test plan
  - Pressure test report
  - Certifications

Deliverables [Appendix A.1] [cont.]

– ***Software Assurance Documents***
  - Software development plan
  - Software requirements document
  - Software requirements verification matrix
  - Software architectural design specification
  - Software users guide
  - Software test reports
  - Software version description document
  - Software analysis report
  - Software verification and validation plan
  - Software verification test procedures
  - Instrument to DCS interface control document

Deliverables [Appendix A.1] [cont.]

- ***Reports, plans, manuals, and other***
  - Instrument operations concept
  - Instrument assembly mass and c.g. ICD analysis report
  - Instrument ICD envelope analysis report
  - Instrument cart/stand ICD analysis report(s)
  - Instrument cart/stand structural analysis report(s)
  - Instrument configuration sheet
  - Instrument maintenance logbook
  - Commissioning plan
  - Operating manual
  - Instrument control software manual
  - Commissioning report
  - Pipeline developers manual
  - Pipeline users manual
  - Maintenance manual
  - Instrument shipping plan
  - Instrument identification list
  - Action item reports
  - Acceptance data package

Deliverables [Appendix A.1] [cont.]

- ***Operating Procedures***
  - Instrument installation procedure
  - Instrument warm functional check procedure
  - Instrument cooldown procedure
  - Instrument cryogen fill procedure
  - Instrument cold functional check procedure
  - EMI test plan
  - Instrument optical alignment plan
  - Ground test plan
  - Instrument removal procedure
- ***Review Chart Packages***
  - Systems Requirements Review chart package
  - Preliminary Design Review chart package
  - Critical Design Review chart package
  - Pre-ship Review chart package
  - Acceptance Review chart package

Deliverables [Appendix A.2]

- ***Appendix A.2 Documentation Delivery Schedule*** identifies the documents due at each Technical Review, and also indicates the expected maturity of each document.
  - This appendix does not define any new deliverable items; Appendix A.2 simply presents the document deliverable item information from Appendix A.1 in a graphical format (shown in the following charts).

Deliverables [Appendix A.2] [cont.]

- Snapshots from ***Appendix A.2 Documentation Delivery Schedule*** (refer to Handbook for more legible list):

Acronym	Definition	Symbol	Definition
SRR	Systems Requirements Review	○	Initial or updated draft release
PDR	Preliminary Design Review	●	Baseline release; typically a final release
CDR	Critical Design Review	▲	Typical updated release following a baseline release (if necessary)
PSR	Pre-Ship Review		
PIR	Pre-Install Review		
CR	Commissioning Review		
AR	Acceptance Review		

Item #	Document	SRR	PDR	CDR	PSR	PIR	CR	AR
12	Project Management Plan	●						
13	Schedule	Update monthly under contract						
14	Monthly status reports	Update monthly under contract						
15	Yearly funding requirements estimates	Update annually						
16	Instrument science and technical performance requirements	●	▲	▲				
17	Instrument science and technical performance verification matrix	○	○	○	○	○	●	●
18	Instrument SI System Specification and ICD requirements verification matrix	○	○	○	○	○	●	●
19	Drawing package		○	●	▲			
20	Quality plan	○	○	●				
21	Electrical systems report		○	○	●			
22	Instrument assembly structural analysis report		○	○	●			
23	Counterweight rack report		○	○	●			
24	PI rack report		○	○	●			
25	System safety assessment		○	○	●			

Note: Commissioning Review (CR) is not applicable for SOFIA 3rd Gen SI

Deliverables [Appendix A.2] [cont.]

Item #	Document	SRR	PDR	CDR	PSR	PIR	CR	AR
26	Pressure test plan			●				
27	Pressure test report				●			
28	Certifications				●			
29	Software development plan	○	○	●				
30	Software requirements document	●	▲	▲				
31	Software requirements verification matrix	○	○	○	○	○	●	●
32	Software architectural design specification		○	●				
33	Software users guide *(FSI only)*				○			●
34	Software test reports				●	●		
35	Software version description document			○	○	●		
36	Software analysis report	As needed						
37	Software verification and validation plan		○	●				
38	Software verification test procedures			○	●			
39	Instrument to DCS interface control document		○	○	●			
40	Instrument operations concept	●						
41	Instrument assembly mass and c.g. ICD analysis report		○	○	●			
42	Instrument ICD envelope analysis report		○	○	●			
43	Instrument cart/stand ICD analysis report(s)			○	●			
44	Instrument cart/stand structural analysis report(s)			○	●			
45	Instrument configuration sheet					●		
46	Instrument maintenance logbook *(FSI only)*							●
47	Commissioning plan				●			
48	Operating manual *(FSI only)*				○			●
49	Instrument control software manual *(FSI only)*				○			●
50	Commissioning report						●	●
51	Pipeline developers manual *(FSI only)*				○			●
52	Pipeline users manual *(FSI only)*				○			●
53	Maintenance manual *(FSI only)*				○			●

Note: Commissioning Review (CR) is not applicable for SOFIA 3rd Gen SI

Deliverables [Appendix A.2] [cont.]

Item #	Document	SRR	PDR	CDR	PSR	PIR	CR	AR
54	Instrument shipping plan				●			
55	Instrument identification list		○	●				
56	Action item reports	As needed						
57	Commissioning data package *(PSI, TDSI)*						●	
58	Acceptance data package *(FSI only)*							●
59	Instrument installation procedure				○	●		
60	Instrument warm functional check procedure *(FSI only)*				○			●
61	Instrument cooldown procedure				○			●
62	Instrument cryogen fill procedure				○	●		
63	Instrument cold functional check procedure *(FSI only)*				○			●
64	EMI test plan				○	●		
65	Instrument optical alignment plan				●			
66	Ground test plan				●			
67	Instrument removal procedure				○	●		
68	Systems Requirements Review chart package	●						
69	Preliminary Design Review chart package		●					
70	Critical Design Review chart package			●				
71	Pre-ship Review chart package				●			
72	Commissioning Review chart package *(PSI, TDSI)*						●	
73	Acceptance Review chart package *(FSI only)*							●

Note: Commissioning Review (CR) is not applicable for SOFIA 3rd Gen SI

Other Useful Information [Appendices]

- ***Appendix C Rack & Patch Panel Distances*** contains distance information for the various SOFIA patch panels and SI Rack (e.g., PI Rack, Counterweight Rack) locations.
- ***Appendix G*** contains samples of the four generic SI hazard reports. Hazard reports (HRs) formally capture the hazard scenario, hazard causes, hazard effects, mitigations, and final hazard category.
  - Appendix G.1, *Generic SI and SI-provided GSE Structural Hazards*
  - Appendix G.2, *Generic SI Cryostat Overpressure and Habitable Atmosphere Hazards*
  - Appendix G.3, *Generic SI - Aircraft Platform Pressure Boundary Hazards*
  - Appendix G.4, *Generic SI and SI-provided EGSE Electrical Hazards*

Science Instrument System Specification
SOF-AR-SPE-SE01-2028
[Rev. B]

SOFIA 3rd Gen. SI (S3GSI) Kick-Off Presentation

2 + 3 February 2016

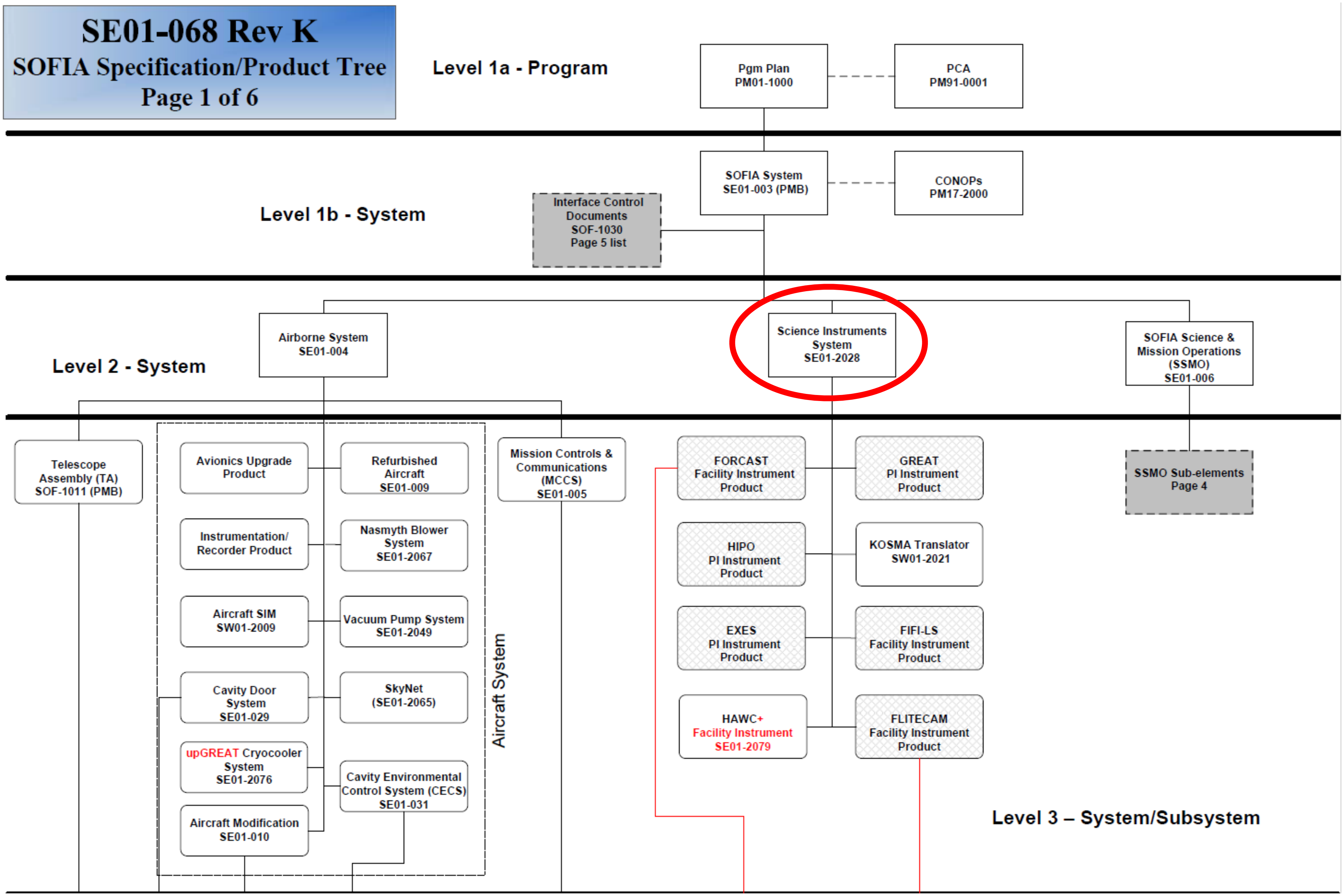
Stefan Rosner / SETI Institute

SOFIA SI Development Engineer

SE01-2028, SOFIA SI System Spec.

- Agenda:
  - SOFIA Specification & Product Tree Context
  - Introduction
  - Requirement Sources / Inputs
  - Binning of Inputs into SE01-2028, OP03-2000, STRD, SoW, O&M Manuals
  - Requirements Organization
  - Revision History
  - Key Changes within SE01-2028 Rev. A and Rev. B
    - Summary of FROM: / TO: changes for Rev. A
    - Summary of FROM: / TO: changes for Rev. B
  - Requirement Verification Breakdown
  - Summary of Requirements in each Section of SE01-2028

SOFIA Specification / Product Tree Context



SE01-2028, SOFIA SI System Spec.

- Introduction:
  - SE01-2028, SOFIA Science Instrument (SI) System Specification, is an OCCB-approved, Level 2 specification that comprises the verifiable design requirements for SI system hardware and software
    - Supported the Announcement of Opportunity (AO) for SOFIA 2nd gen. SIs
    - Many of the suite of SOFIA 1st gen. SIs were built well before the development and release of SE01-2028 Rev. – in April 2011
    - Many were also initiated under the Airworthiness auspices of the FAA, prior to SOFIA Program redirection to adopt internal NASA Airworthiness requirements under direction of AFRC Operations Engineering and the SI Airworthiness Team (SIAT)
      - SIAT prepares a letter or recommendation re: the airworthiness of the SI and presents any findings at a "Tech Brief" to the AFRC Airworthiness & Flight Safety Review Board (AFSRB), the board with ultimate responsibility and authority for integrated Observatory Airworthiness certification
  - Important that the program capture, document, baseline and control those verifiable requirements necessary for SIs to ensure compliance with both SOFIA Program Systems Engineering & Integration (SE&I) Verification and Airworthiness (SIAT) processes
  - Stated goal was to define the "minimal sufficient set" of requirements to provide maximum design latitude to instrument developers
    - It is recognized that the instrument developers are really the experts at collecting photons and generating scientific data, and generally have significant experience with observatories and observing, so the intent is really just to define those additional requirements that are unique to our airborne observatory and associated airworthiness processes

SE01-2028, SOFIA SI System Spec.

- Introduction [cont'd]:
  - Because SI science and technical performance requirements are specific to the instrument type and the investigations proposed, these are generally captured in each instrument's Science and Technical Performance Requirements Document (STRD)
    - Since SI functional and technical performance requirements are outside the scope of the SE01-2028, the spec. may appear to be dominated by SI Airworthiness Certification and Safety driven requirements
  - Requirements that were determined to be limited to Mission Success / Mission Assurance vs. Airworthiness / Safety were deemphasized or "demoted" as a programmatic risk management decision
    - Some appear only as goals or guidance ("should" statements) vs. verifiable ("shall" statement) requirements
    - Others were waived in favor of PI / SI team risk assessment and discretion, e.g., "Shake & Bake" Environmental Acceptance Testing
  - Within SE01-2028 (§3.11 + ParID 3.1.2) are requirements for SIs to comply with 15 Interface Control Documents (ICDs), as applicable
  - Requirements are "owned" by either SE&I or SIAT
    - Determines which organization is the applicable V&V Compliance Authority

SE01-2028, SOFIA SI System Spec.

- Requirement Sources / Inputs:
  - SOFIA Science Instrument Airworthiness Certification Guide inputs provided by SOFIA Aircraft Platform Project Operations Engineering
    - Included LHe dewar Loss of Vacuum (LoV) pressure rise model that became the basis for SE01-2028 Rev. – Appendix C
  - SOFIA Safety & Mission Assurance Inputs provided by SOFIA Aircraft Platform Project and Science Project Chief Safety Officers
  - Level 1 requirements from SE01-003, SOFIA System Specification, identified for allocation to SIs via "flowdown" to SE01-2028
  - Level 1 requirements from SE01-013, SOFIA Observatory Specification (deprecated), identified by Spec. Team 2 for allocation to SIs via "demotion" to Level 2 SE01-2028 spec.
  - SI Cart / Stand structural design / analysis / test requirements as risk mitigation in response to mishaps / close calls from ground operations w/ 1st generation SI GSE
- Requirement refinement, negotiation and vetting by stakeholders @ SRR
  - Including SI Dev. Management, Project Scientists, SE&I, Operations Engineering / SIAT, S&MA and Chief Safety Officer

SE01-2028, SOFIA SI System Spec.

- “Binning” of inputs into categories for inclusion in the following documents, based on the following criteria:
  - **SOF-AR-SPE-SE01-2028, *SI System Specification*:** Verifiable, design-to requirements applicable to the SI System itself
  - **SCI-AR-HBK-OP03-2000, *SI Developers’ Handbook*:** No Verification Required (NVR) design goals, design guidance, narratives and definition of the processes for preparing an instrument for SOFIA, and definition of operational environments
  - **Statement of Work (SoW):** Process requirements applicable to the SI Developer organization (vs. the SI System), e.g., requirements to follow the System Safety and Airworthiness Certification processes, defined within the SI Developers’ Handbook
  - **SI Operation & Maintenance (O&M) Manual(s):** Requirements for recurring / ongoing maintenance activities, periodic load testing and inspections, recertifications, etc.
  - **Science and Technical Requirements Document (STRD):** These requirements are specific to individual investigations and instruments, and define the scientific performance requirements for the instruments to be verified prior to or during the instrument commissioning flights
  - **ICDs:** Contain functional and physical requirements that govern the interfaces with Observatory systems. These requirements are verified through the ICD Verification & Validation (V&V) and safe-to-mate processes coordinated by Science Project SE&I
- SE01-2028 Defines V&V Methodologies (i.e., A, I, D, T) as well as the V&V Compliance Authority (i.e., SE&I or SIAT)
  - However, detailed definition of Verification Activities and “phasing” of Verification deliverables for SE01-2028 as well as sub-tier ICDs is defined within SV05-2057

Spec. Requirements Organization

- 3.1.# Functional
- 3.2.# Performance
- 3.3.# Physical
- 3.4.# Environmental
- 3.5.# Safety
- 3.6.# Reliability
- 3.7.# Maintainability
- 3.8.# Logistics
- 3.9.# Human Factors
- 3.10.# Part Materials & Processes
- 3.11.# Interfaces

SE01-2028, SOFIA SI System Spec.

- Revision History:
  - **SE01-2028 Rev. –** (initial release April 2011) was approved by SOFIA Program Management Board (PMB)
    - Subsequent to the merging of the SOFIA Science Project and Airborne Platform Project, SE01-2028 and other Level 2 specifications (and many ICDs) were "demoted" from PMB to OCCB control
  - **SE01-2028 Rev. A** (15 July 2015) was approved by the OCCB
  - **SE01-2028 Rev. B** (4 Nov. 2015) was approved by the OCCB
- Note that the SOFIA Program Library published at http://science.nasa.gov/researchers/sara/library-and-useful-links/ included SE01-2028 {DRAFT} Rev. A vs. the current Rev. B
  - Rev. B has subsequently been formally approved and released, and is now available at http://soma.larc.nasa.gov/sofia/sofialib.html
  - The bulk of the changes to SE01-2028 most relevant to the 3rd gen. candidate SIs (SHASTA and HIRMES) were incorporated into Rev. A

Key changes in Rev. A and Rev. B

- Summary of FROM: / TO: changes for Rev. A:
  - Approved and released to support Announcement of Opportunity (AO) for 3rd gen. SOFIA SIs (ROSES-2015 Appendix D.12, 9 July 2015)
  - Updates to reflect inputs, lessons learned, etc. since Rev. – , April 2011)
  - Clarify / correct applicability of GSE structural design analysis and test requirements
  - Relaxation of SI grounding specification from 10 milli-Ohms to 70 milli-Ohms
  - Updates to Appendix C to reflect use of NESC-approved Dr. Eugene Ungar models to estimate LHe reservoir P_{max} (in lieu of Dr. Eric Smith / Cornell Univ. model)
  - Updates to LHe reservoir safe venting requirements and Qualification / Acceptance Test & Analysis requirements (several statements which provided guidance within Notes / Rationale fields have been recast as explicit, verifiable requirements)

Key changes in Rev. A and Rev. B

- Summary of FROM: / TO: changes for Rev. B:
  - Clarify Cryogen Reservoir & Vent / Neck Tube Qualification Test requirements:
    - SI Dev., SIAT and S&MA stakeholders (and AFRC Pressure Systems Manager) have agreed to a process by which COTS items such as metal bellows used as flexible elements within cryogen reservoir vent / neck tubes may be excluded from integrated cryogen reservoir assembly Qualification pressure tests, reflecting a "hybrid" between Proto-Flight and Prototype Qualification approaches
    - This was already reflected in SE01-2028 Rev. A, ParID 3.5.3.3.1 within the Notes / Rationale field, but it was agreed that up-front guidance re: the additional testing that *will be* required by the SIAT would be beneficial, should an SI developer wish to pursue this hybrid Qualification approach
    - While this coordination and agreement is technically substantive, it is reflected in SE01-2028 Rev. A.1 only via clarifications in the Notes / Rationale field; the technically substantive changes are incorporated into the corresponding entry within SOF-NASA-REP-SV05-2057 Rev. – , the requirements Verification Matrix Template that defines the Verification activities and phasing associated with SE01-2028 Spec. and ICD requirements

Key changes in Rev. A and Rev. B

- Summary of FROM: / TO: changes for Rev. B [cont'd]:
  - Update Notes / Rationale for ParID 3.1.1 to acknowledge routine 30 ~ 45 minute lapses of Observatory power, e.g., during tow-out from hangar to flight line
  - Reflect NESC approval and formal release of NESC-RP-15-01017:
    - SE01-2028 Appendix C was updated for Rev. A based on a draft release of this NESC report
    - An assessment of the technical content of NESC-RP-15-01017 has been conducted by SI Dev. and S&MA staff, and no technical changes are considered necessary
    - Therefore, the related changes are limited to adding NESC-RP-15-01017 to §2.3.3, Other Reference Documents, and inserting citations of this report to Appendix C and ParIDs that reference Appendix C

Key changes in Rev. A and Rev. B

- Summary of FROM: / TO: changes for Rev. B [cont'd]:
  - Correct errata in Trace to SE01-003 parent requirements for several GSE (and related) non-airworthiness requirements within§3.5:
    - SE&I trace analysis during development of SE01-2028 Rev. A pointed to SE01-003 ParID 3.5.5 (airworthiness process) for GSE requirements
    - Further discussions within SE&I (Observatory V&V Lead, RM Lead) have identified SE01-003 ParID 3.5.1 as a suitable parent for safety-related GSE requirements
    - "The SOFIA System shall comply with the Program Safety and Mission Assurance Plan (SOF-1086)"
  - Administrative updates:
    - Correct several document titles
    - Add missing acronyms (and delete duplicates) from Appendix D
    - Clean-up typographical errors

Requirement Verification Breakdown

SOF-AR-SPE-SE01-2028 Rev. B , SOFIA SI System Specification							
Requirement V&V Breakdown							
§	**Requirements**	**Total Req'ts**	**Inspection**	**Demonstration**	**Analysis**	**Test**	**Total V&V**
3.1	Functional	5	1	4	1		6
3.2	Performance	3		3	2	1	6
3.3	Physical						
3.4	Environmental						
3.5	Safety	23	14	1	18	8	41
3.6	Reliability						
3.7	Maintainability						
3.8	Logistics	3		1	3		4
3.9	Human Factors	1		1	1		2
3.10	PMP	7	7				7
3.11	Interfaces	14	Refer to SV05-2057 Rev. – , ICDs Section				
Total		56	22	10	25	9	66

Summary of Requirements by Section

- Summary of Requirements in each Section of SE01-2028:
  - 3.1, Functional:
    - SI tolerance of various unannounced power outages w/o permanent functional or performance degradation
    - SI Interface w/ MCCS via SCL
    - Tagging of SI data w/ SOFIA-provided time stamp and GPS position
    - FSI compliance w/ pipeline data processing requirements
  - 3.2, Performance:
    - SI data flux calibration to within 20% RMS
    - FSI real-time estimates of cumulative S/N to support inflight flight planning and observing strategy decisions
    - SI entrance pupil optical alignment w/ SOFIA TA exit pupil
  - 3.3, Physical:
    - N/A
  - 3.4, Environmental:
    - N/A

Summary of Requirements by Section

- Summary of Requirements in each Section of SE01-2028 [cont'd]:
  - 3.5, Safety:
    - Use of self-locking / retaining fasteners externally (FOD control) and for critical structures
    - Flight and GSE structural design analysis and proof test load factors, GSE stability
    - Cryogen reservoir / PVS safety: Structural, redundant vent paths and PRDs, Qualification and Acceptance analyses and pressure testing, GSE PVS, flex line restraint
    - Electrical safety, wire sizing and overcurrent protection, SI grounding
  - 3.6, Reliability:
    - N/A
  - 3.7, Maintainability:
    - N/A
  - 3.8, Logistics:
    - Expendable cryogen replenishment service interval
    - SI installation and removal time
  - 3.9, Human Factors:
    - SI design, operations and in-flight access consistent w/ operational constraints

Summary of Requirements by Section

- Summary of Requirements in each Section of SE01-2028 [cont'd]:
  - 3.10, Parts, Materials & Processes:
    - Metal stock / fastener certs. & CMTRs for SI flight H/W critical structures
    - Metal stock material / temper call-outs for GSE critical structures
    - Electrical cable and connector labeling
    - PVC insulation / jacketing prohibition (w/ process for approval of PVC in COTS)
    - Connector sealing to support pressure boundary of aircraft
  - 3.11, Interfaces:
    - SI Envelopes (installation, servicing, operating)
    - SI to TA interfaces (mechanical, electrical power, signal)
    - SI PI Rack to Aircraft
    - SI CWR to TA
    - SI data format (FITS) and required Keywords to support DCS ingestion
    - SI to MCCS (electrical power, signal, connector P/Ns and pinouts)
    - SI to TA SMCU (chopping secondary mirror)
    - SI GSE to Aircraft and SSMO facility constraints
    - SI to TA Alignment Simulator (TAAS)
    - SI to Cryocooler System
    - SI to Vacuum Pump System (VPS)

SOFIA Airborne SI Support
Observatory Mission Systems

SOFIA 3rd Gen. SI (S3GSI) Kick-Off Presentation

2 + 3 February 2016

Stefan Rosner / SETI Institute

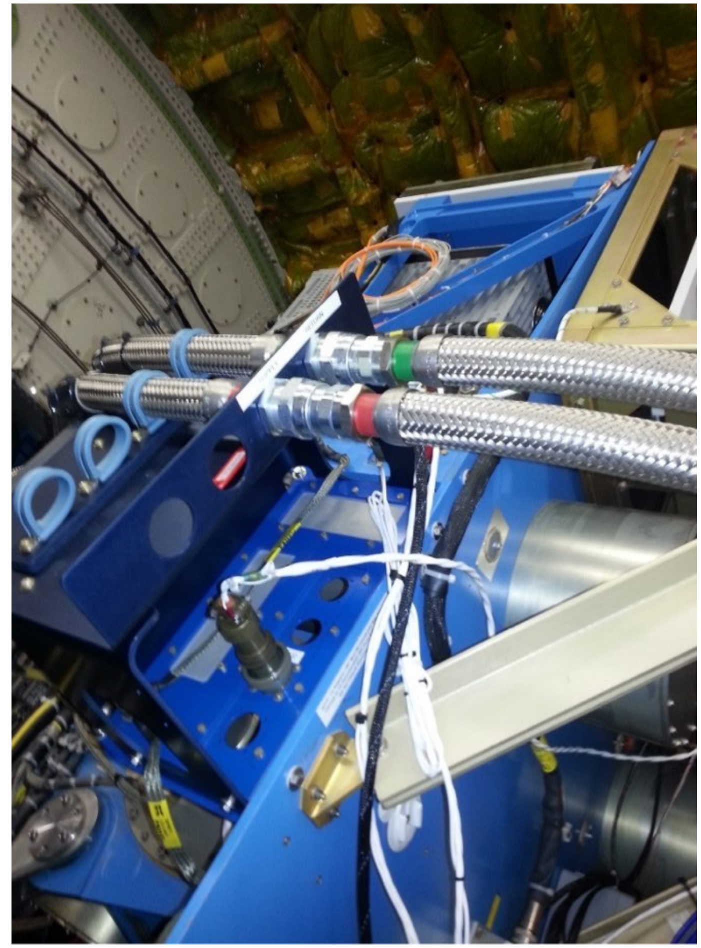
SOFIA SI Development Engineer

SOFIA Observatory Mission Systems

- Agenda:
  - Airborne SI Support Observatory Mission Systems
    - Cryocooler System
    - Vacuum Pump System (VPS)

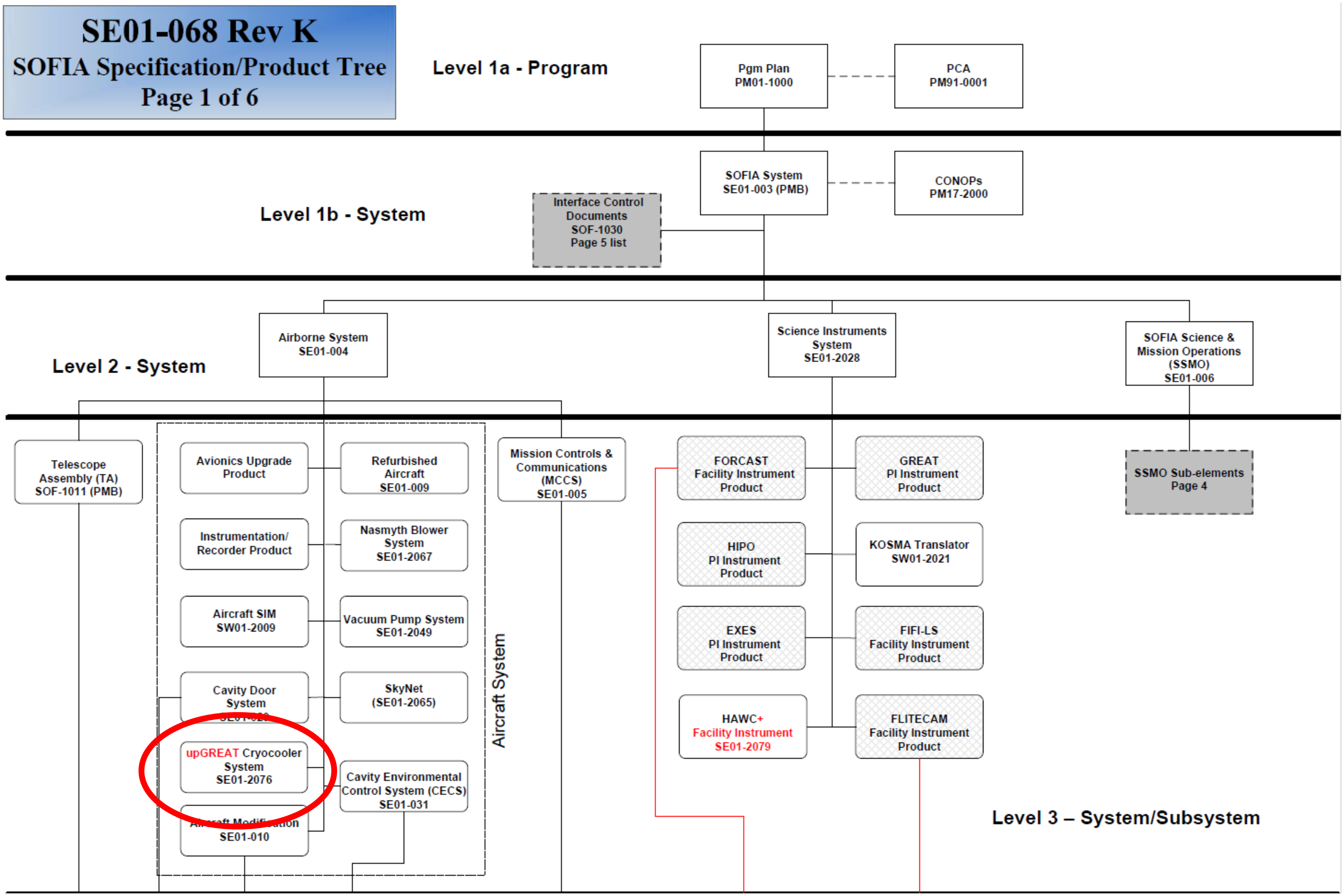
Cryocooler System

- Phase 1 Cryocooler System configuration



- Air cooled, SHI CSA-71A compressor, with pitch-axis gimbal and shock mount in main cabin
- External supply line oil mist Adsorber and molecular sieve filter installed in overhead liner
- Added instrumentation for acceleration / tilt, supply & return pressures, temperatures
- Analog and discrete signal I/F to SI for remote control / reset, HK data monitor / record

SOFIA Specification / Product Tree Context



Cryocooler System

- Introduction:
  - All 1st and 2nd gen. SOFIA SIs used expendable liquid cryogens (LN2, LHe) to cool their cryostats and detectors to ~ 4.2K
    - Some SIs use various means to achieve lower temperatures
      - FIFI-LS uses the Vacuum Pump System (VPS) to reduce the pressure in one of the LHe dewars to achieve a phase change at the "λ point" to LHe-II @ ~ 1.7K
      - HAWC+ will use an Adiabatic Demagnetization Refrigerator (ADR) and a sorption cooler to achieve milli-Kelvin temperatures
  - Many ground-based observatories now support the use of Closed-Cycle Cryocooler (CCC) systems to achieve 10K and 4.2K temperatures w/o the use of expendable LN2 or LHe
    - The use of CCC systems reduces the operational costs and some logistical risk associated with the use of LHe, which is a limited, non-renewable resource that is becoming increasingly expensive
  - That said, the use of CCC systems does somewhat complicate ground operations and ground crew staffing due to the need for quasi-24/7 power aboard SOFIA between flights during observing campaigns
    - Collateral issues and costs associated with staffing related to compliance w/ AFRC Centerwide Code O Aircraft Maintenance & Safety Manual (AM&SM) Procedures (DCP-O-001), §7-5.0, Electrical Power Guidelines

Cryocooler System

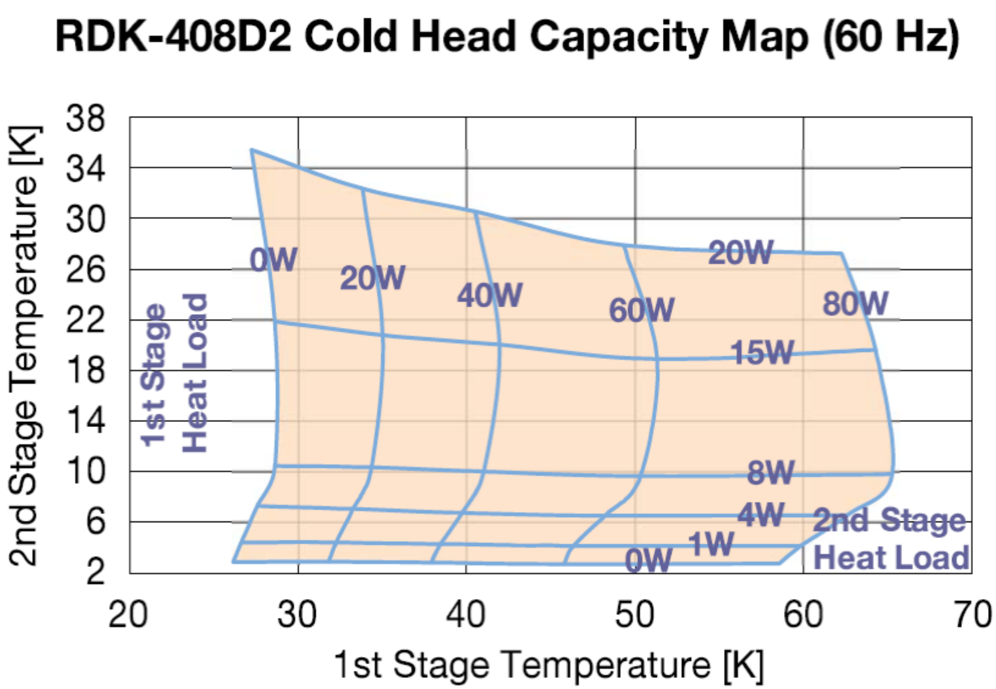
- Cryocooler-related documents:
  – APP-DA-PLA-PM17-2076 Rev. – , SOFIA Cryocooler Concept of Operations (ConOps)
  – APP-DA-SPE-SE01-2076 Rev. A , SOFIA Phase 1 Cryocooler System Specification
    - Note that the SOFIA Program Library published at http://science.nasa.gov/researchers/sara/library-and-useful-links/ presently does not include the PM17-2076 ConOps, and includes SE01-2076 Rev. –
    - SE01-2076 Rev. A was presented to the SOFIA Engineering Review Board (ERB) on 1/13/2016, and was on the agenda for a decisional review at the OCCB on 1/20/2016, but was “tabled” until the OCCB on 1/26/2016 due to time constraints
    - Rev. A is largely just a “rescoping” effort to make this document specific to Phase 1 of the Cryocooler System (i.e., a single, air-cooled He compressor), and less specific to the upGREAT SI (first user of the system)
  – APP-DA-ICD-SE03-2059 Rev. – , Cryocooler System to Science Instrument ICD (CRYO_SI_01)
  – APP-DF-ICD-SE03-2060 Rev. – , Cryocooler System to Aircraft System ICD (CRYO_AS_01)
    - Both of these ICDs will be undergoing revision to Rev. A in the next few months to reflect *minor* changes in the as-built configuration, notably…
    - He line routing details and U404 He QD patch panel design details and location
    - Change to discrete I/O signaling interface between Cryocooler System controller and SI

Cryocooler System

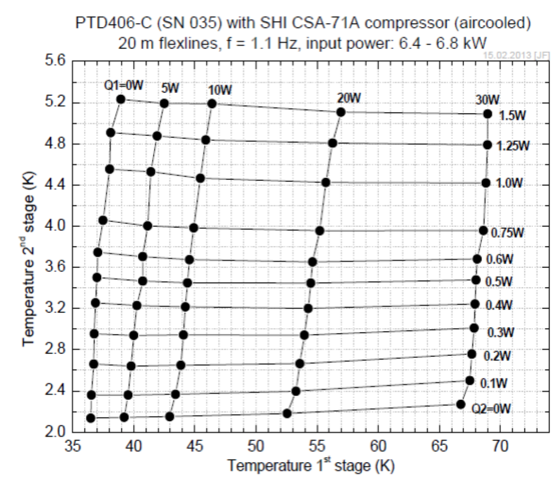
- Phased Cryocooler System Development:
  - At least one SOFIA SI (upGREAT) will ultimately require 2 Cryocooler He compressors to drive 2 Pulse Tube cold heads (for 2 distinct cryostats / channels)
  - For a variety of programmatic and technical reasons, during early development of the Cryocooler System ConOps and Specification documents, and review at SRR, the decision was made to start with a single air-cooled compressor Phase 1 Cryocooler System
    - The Phase 1 Cryocooler System is temporarily installed on SOFIA when needed to service an SI, and is a “pathfinder” for a more capable, permanently installed 2-compressor Phase 2 Observatory mission system facility
    - Follow-on Phase 2 development *may* be pursued in the near future
  - The Phase 2 Cryocooler System is presently being scoped and defined
    - Possible / likely use of water-cooled compressors would add complexity, but provide flexibility re: heat rejection (~20 kW) during ground and airborne operations
    - May or may not use pitch axis gimbal mounting (pending dev. testing results)
    - Likely interface w/ SOFIA MCCS for Control & Monitoring, HK data archival

Cryocooler System

- Cryocooler System Performance:
  - Thermal performance (i.e., heat that can be sinked at 1st and 2nd stage of mated cold head) is strongly dependent on the SI cold head (specified and provided by the SI developer), as well as a number of tunable parameters and fixed constraints
    - Tunable: He loop static pressure (within limits), cold head orifices / valves, pulse tube rotary valve frequency
    - Fixed: Performance of selected compressor(s), line lengths and diameters, QD interface sizes, 20 kVA power budget (400 Hz aircraft bus), etc.
  - Performance maps excerpted from SE01-2076 Appendix A below are representative of the Phase 1 Cryocooler System SHI CSA-71A compressor with a) SHI G-M cold head; and b) transMIT PTD-406C Pulse Tube cold head



Operation of PTD406-C with air-cooled SHI compressor CSA-71A



Minimum temperature at 2nd stage	< 2.4 K
Cooling power 2nd stage	≥ 0.75 W @ 4.2 K
Cooling power 1st stage	≥ 20 W @ 57 K
Cool down time to 4.2 K	< 75 minutes *(no additional heat load)*
Input power in steady state	6.4 – 6.8 kW
Length of split line to rotary valve	75 cm
Weight of cold head with rotary valve	20 kg without vacuum vessel and radiation shield
Frequency controller for rotary valve mains supply	220 V / 50 Hz, ≤ 40 W el. power consumption

Cryocooler System

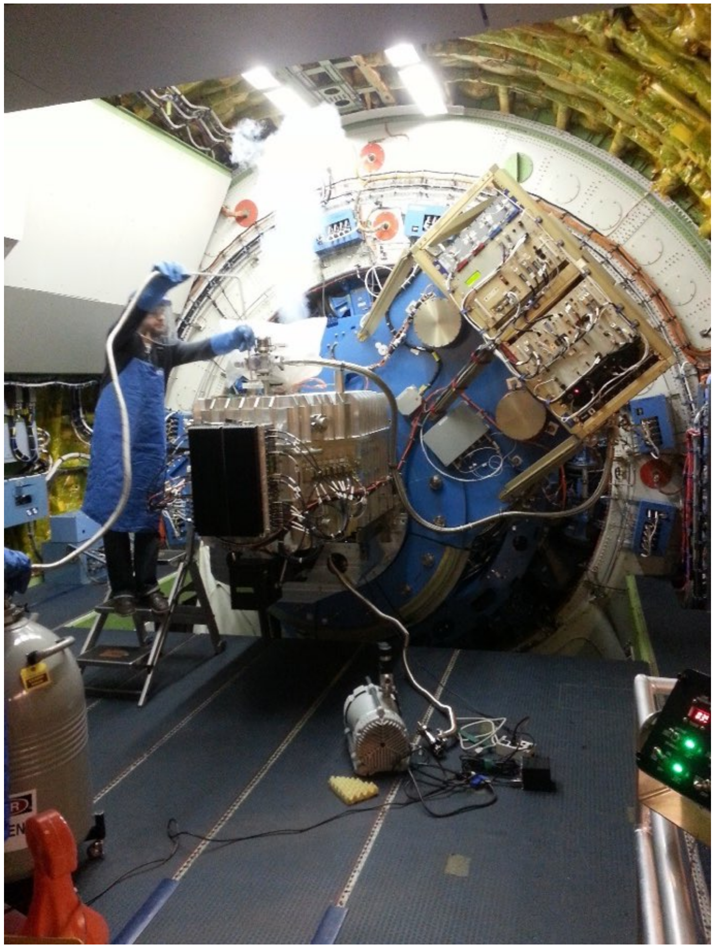
- Cryocooler System ConOps and operational constraints:
  - Cryocooler He scroll compressors and oil separation subsystems are known to be sensitive to tilt / acceleration, with ±5°being a typical spec. for maximum tilt
    - The dynamic environment of the SOFIA aircraft with respect to pitch angle and U-axis take-off / landing accelerations can easily exceed the equivalent of ±5°tilt
    - Roll angles (i.e., during aircraft turns) are generally not an issue, as coordinated flight w/ banked turns results in an effective resultant acceleration that stays very nearly normal to the aircraft deck
    - Use of a pitch axis gimbal mount addresses changes in aircraft pitch angle and *most* take-off / landing accelerations
    - In a typical flight, there has been no need to shut off the compressor during take-off and climbout, and is turned off briefly during landing phase only as a precautionary measure
      - Aircraft turns during ground taxiing maneuvers and sometimes approach or even briefly exceed lateral acceleration limits
      - This can be somewhat mitigated via care to control speed during ground taxi maneuvers, but minimum speeds need to be maintained during turn maneuvers to prevent the aircraft from getting “stuck” with the nose gear acutely turned

Cryocooler System

- Cryocooler System ConOps and operational constraints [cont'd]:
  - There are also some unavoidable power interruptions and transients that should be understood and planned for
    - 30 ~ 60 minute power off during SOFIA tow-out from shore power in hangar to power cart connection at flight line (or APU start)
    - Much shorter power transients during cut-over from APUs or ground power cart to engine generator power, and vice versa
    - SI development must understand and anticipate such interruptions of compressor operations, and confirm adequate thermal recovery time prior to observations
    - For the longer interruptions, possible loss of cryopumping (and associated impact to cryostat vacuum) should be considered
      - Note that the onboard Vacuum Pump System (VPS) is suitable only for medium or technical vacuum, and is generally inadequate for pumping out cryostat vacuum jackets
    - Project team is also looking into developing a "shore power" interface to support "24 / 7" powered Cryocooler operations using hangar utility power or a ground power cart, without the need to power up the SOFIA aircraft (Observatory power bus #4)
  - SI-provided cold heads are also typically subjected to tilts and accelerations, including TA ELevation angle
    - Gifford-McMahon technology cold heads are less sensitive to orientation than Pulse Tube technology cold heads, as well as He loop contamination
    - However, Pulse Tube cold heads have fewer moving parts (none, aside from a rotary valve which can be remotely mounted and vibration isolated from the Pulse Tube itself) and may be preferable from vibration and maintenance points-of-view

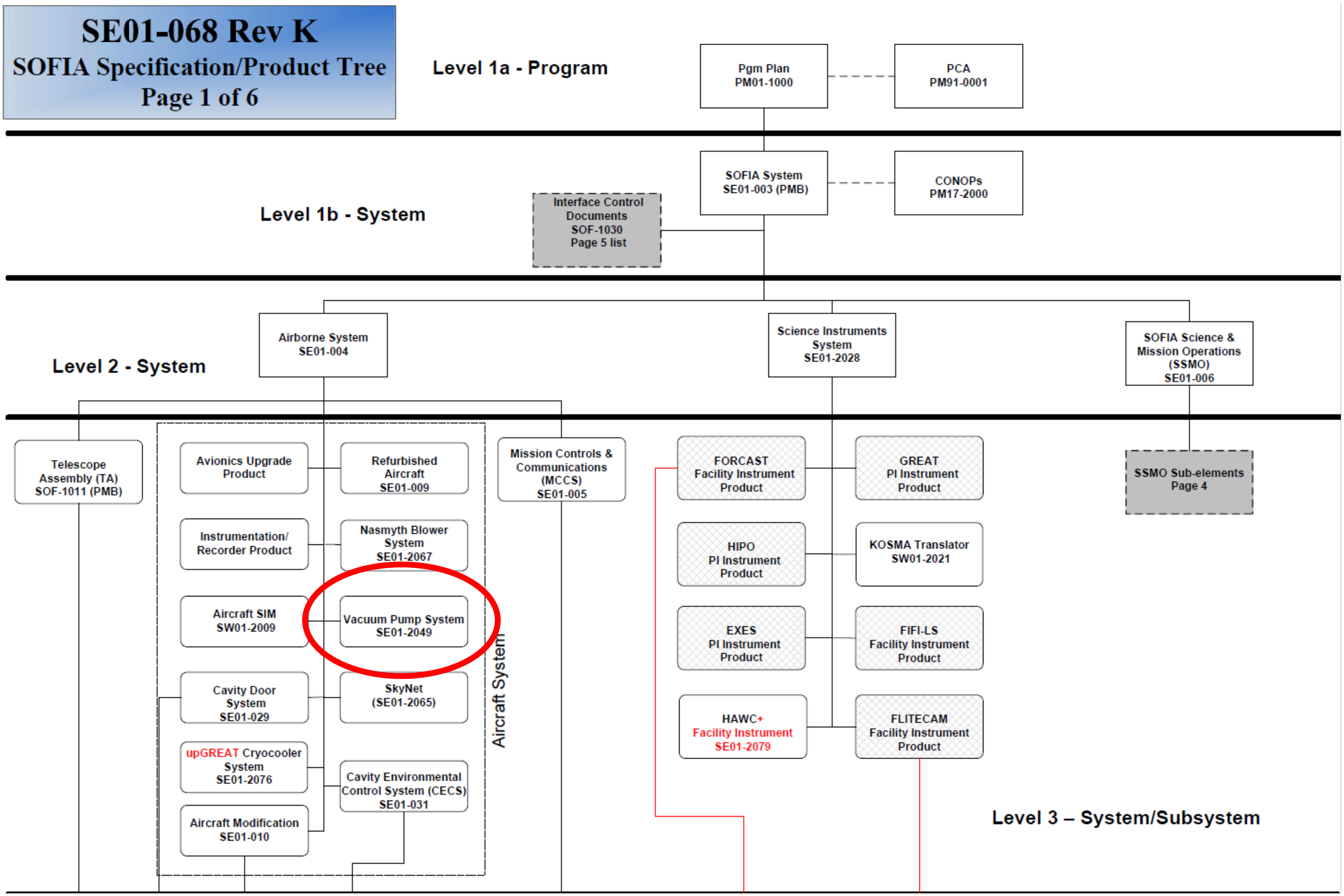
Vacuum Pump System (VPS)

- VPS configuration



- Two pallet-mounted (2) Edwards XDS35i oil-free scroll vacuum pumps
- Flow manifold for each pump to allow (manual) regulation of pump-down rate
- Vacuum lines routed through CLA to VPS-to-SI KF flange I/F on TA counterweight plate
- Used to pump on cryostats to reduce boiling point of cryogen, or pump-out of TA INF “tub”

SOFIA Specification / Product Tree Context



Vacuum Pump System (VPS)

- Introduction:
  - Some SIs use various means to achieve lower temperatures
    - FIFI-LS uses the Vacuum Pump System (VPS) to reduce the pressure in one of the LHe dewars to achieve a phase change at the “λ point” to LHe-II @ ~ 1.7K
  - VPS can also be used to pump out the TA INF “tub” or SI pressure coupler
    - Purge and back-fill w/ inert / dry gas, e.g., for protection of hygrophilic optical windows
  - ConOps use cases and design support simultaneous use of both pumps
  - VPS is capable of medium or “technical” vacuum, but does not replace turbomolecular pumps for high vacuum applications such as cryostat vacuum jackets

Vacuum Pump System (VPS)

- VPS-related documents:
  - SCI-US-PLA-PM17-2074 Rev. – , Vacuum Pump System (VPS) Concept of Operations (ConOps)
  - APP-DA-SPE-SE01-2049 Rev. – , Vacuum Pump System (VPS) Specification
  - APP-DA-ICD-SE03-2022 Rev. – , Vacuum Pump System (VPS) to Science Instrument ICD (VPS_SI_01)
  - APP-DF-ICD-SE03-2054 Rev. – , Vacuum Pump System (VPS) to Aircraft System ICD (VPS_AS_01)

Science Instrument Software

SOFIA 3rd Gen. SI (S3GSI) Kick-Off Presentation
2 February 2016

Bill Wohler / SETI Institute
SOFIA SI Software Interface Lead

Science Instrument Software

- Phases
- Software airworthiness
- XML configuration file
- Telescope control software
- Instrument control software
- Data processing
- FSI software responsibilities
- Testing

Phases

- Phase A – Concept and Technology Development
  - Quantities of software items are defined
  - Plans for controlling software development are completed

➔System Requirements Review (SRR)

- Phase B – Preliminary Design and Technology Completion
  - Appropriate descopes to software has been quantified
  - Preliminary requirements are identified
  - Nominal operating scenarios are identified
  - Design and development plans are defined
  - Verification strategies are defined including test environments

➔Preliminary Design Review (PDR)

Phases (con)

- Phase C – Final Design and Fabrication
  - Requirements changes since PDR are identified
  - Current operating scenarios are identified
  - Current software performance estimates exist and meet requirements
  - Software Requirements Document (SRD) with V&V matrix mapping requirements to subsystems or CSCIs is approved
  - Software Development Plan is approved and includes lines of code estimate, number of builds, tools, and procedures to be utilized, and the verification strategy including planned test environments

➔ Critical Design Review (CDR)

- Phase D – System Integration and Test & Acceptance Review
  - SI software documentation in compliance with the SOFIA Software Management Plan (SMP)
  - Functional and Physical Configuration Audit (FCA/PCA) has been performed

➔ Pre-ship review (PSR)

  - Requirements and design changes to software since CDR and attendant rationale are documented
  - Software interface testing in the SIL or HIL have been successfully completed

Software Airworthiness

- The instrument software shall meet the following safety criteria:
  - Does not cause or contribute to the science instrument system or aircraft reaching a hazardous state
  - Detects or takes corrective action if the instrument system reaches a hazardous state
  - Mitigates damage if a failure occurs
- Additional requirements may be levied if the science instrument software is capable of:
  - Causing a hazardous condition
  - Preventing or controlling a hazardous condition
  - Is the only method of detecting an actual or impending hazardous condition

XML Configuration File

- *<si>_data.xml*
- Establishes SI's interface with MCCS
  - SCL commands and response items
  - Alerts and alarms
  - Housekeeping values
  - Defaults: mode, focus, scaling, boresight pixels, rotation
- Instrument scientists will assist

Telescope Control Software

- Required deliverable
- Requirement 3.1.2 from the SE01-2028 says that MCCS_SI_04 specifies the communication between the instrument and the telescope
- Documents the SOFIA Command Language (SCL)
- Example of matched chop-nod commands

  1 sma.chop coord_sys=ERF pos_ang=270.0 amplitude=90.0 tip=0.0 tilt=0.0 profile=2 settling_time=5.0 sync_src=external
  2 ta_pos.goto pos=great_target(ra=23.461375(units=degrees) dec=89.015639(units=degrees) centroid=trc_aoi3 chop=plus inertial=yes) track_mode=centroid
  3 nod.define coord_sys=ERF pos_angle=270.0 amplitude=90.0 amp2=90.0 profile=3 track_pos_a=nodtracka track_pos_b=nodtrackb track_pos_x=nodtrackx
  4 coord.set si.integ=1
  5 coord.set si.integ=0 si.exptime=40 si.utcstart=1402630800.01 si.utcend=1402630840.01
  6 nod.goto pos=b
  7 coord.set si.integ=1
  8 coord.set si.integ=0 si.exptime=40 si.utcstart=1402630900.01 si.utcend=1402630940.01

- Example of housekeeping

  22 I mission_id="2015-12-18_GR_F270" coord.pos.sibs.dec=-5d28m26.000s coord.pos.sibs.ra=5h35m18.100s coord.pos.sibs.vpa=34.956998 coord.sky_los_rate=6.750509 das.adc_1_2hz.static_air_temp=-62.500000 das.ic1080_10hz.baro_alt=38020.000000 fltexec.fltexec_data.leg_seq=5 sma.focus_fcm_t_calc=-759.330126 ta_scs.fcm_status.fcm_act_t=-766.000000

- Additional information provided in SCL Users Manual (SCLUM)

Instrument Control Software

- Controls instrument and chopper
- Drives observations
- Collects data (see next slide)
- Since software will ultimately be maintained by the SOFIA program, the use of the use of modern, well-used, languages and OSs and keeping them up to date is preferred

Data Processing

- Level 1 data files
  - FITS
  - Requirement 3.11.7 from the SE01-2028 says that the DCS_SI_01 specifies the format of the files for ingestion, including required header keywords, for example:
    - AOR_ID
    - MISSN-ID
    - FLIGHTLG
    - OBSRA
    - OBSDEC
  - Additional requirements from the SE01-2028 levy constraints on the data written, such as the use of NTP for timestamps and GPS information for current location
  - All files copied to archiver via NFS by end of flight
- Data Analysis Pipeline
  - Algorithms and documentation are required deliverables to allow the SOFIA Science Mission Operations Center (SMOC) to develop data analysis pipelines per requirement 3.1.5 and 3.2.1 from the SE01-2028 and SCI-US-SPE-SE01-2073, SOFIA Science Data Processing System Specification

FSI Software Responsibilities

- Software development and documentation requirements
  - NPR 7150.2B Class C and NASA Software Engineering Handbook
  - SOFIA Software Management Plan (SMP)
    Defines the SOFIA implementation of NPR 7150.2
- Software deliverables include:
  - Instrument control software
  - Software and test scripts required to calibrate or maintain the instrument
  - Including executables, source code, APIs, libraries, make files, and other files required to build the executables

FSI Software Responsibilities (con)

- Documentation deliverables include:
  - Software Development Plan (SDP)
  - Software Requirements Document (SRD)
  - Software Requirements Verification Matrix
  - Software Architectural Design Specification
  - Software User's Guide
  - Software Test Reports
  - Software Version Description Document (VDD)
  - Software Media Release
  - Software Analysis Report (SAR)
  - Software Verification & Validation Plan (SVVP)
  - Software Verification Test Procedures
  - Instrument to DCS Interface Control Document (ICD)

Testing

- Unit tests
- Telescope control software
  - System or integration tests called *Tier* testing, on SILs (or HILSs)
    - Tier 1 - Basic Connectivity (logging in)
    - Tier 2 – HK Data Acquisition (housekeeping)
    - Tier 3 - Command Handling (sending commands)
    - Tier 4 - Observing Scenarios (actual observing tests on an exciting star called HIP 7238)
  - Tier tests should be completed before shipment
  - Telescope Operators (TO) will help you prepare and run the test procedures for these tests
- Instrument control software

Data Processing for 3rd Gen Instruments

Data Processing: After Acceptance

- For SOFIA Facility Science Instruments:
  - SMO executes data processing pipeline and applies calibration procedures
- Data products
  - Level 1 = raw
  - Level 2 = artifact-removed, useful format
  - Level 3 = L2 calibrated to physical units
  - Level 4 = higher-level (e.g. coadds, mosaics)
- Operations
  - L2 products produced within 5 days of end of each flight series
  - L3 products produced within 15 days of end of each flight series

Data Processing: Development

- From the proposal Call Section 5.6.3
  - "Properly reduced SOFIA data will require a data processing pipeline that can account for, among other things, wavelength calibration, flat fielding, detector signatures, etc. The development and delivery of functioning algorithms, and associated supporting documentation…is a required component of the selected instrument. Functioning algorithms can include, for example, software code or pipelines developed and used by the development teams during the implementation and commissioning phases. Consequently, proposals should specifically address pipeline development, and any such activities should be accounted for in the proposed schedule and budget."
- Data Processing Plan SCI-US-PLA-PM17-2010
  - Section 4 "Software Development Plan"

Data Processing: Preliminary Delivery

- Due date: **SI delivery – 6 months**

  "The delivery must include sample data products at each level (including calibration products), and a version of the **processing code** that is at least skeletal, such that [it] can be interfaced with the DCS pipeline executive and data handling."
- Comply with FITS standards and the SOFIA **keywords** (DCS Keyword Dictionary and the DCS-SI ICD)
- **Ancillary files** such as bad pixel masks, darks, etc. (and the method for generating those files) shall be included.
- **calibration procedure** shall be outlined. (The astronomical aspects of calibration are to be covered in a separate **Calibration Plan**.)
- Images: World Coordinate System (**WCS**) derived from the telescope keywords provided on-board by the MCCS.
- Spectrographs: a complete specification of the **wavelength** of each pixel shall be provided

Data Processing: “Final” Delivery

- Due date: **Acceptance Review – 3 months**
- Requirements or Specification Doc
- Source code
- Software Version Description (build and deploy instructions; known issues list)
- SI-DCS ICD updates (including all keywords needed by pipeline)
- Users Guide
  - targeted to SMO staff, who will be operating the pipelines after acceptance of the instrument. The Instrument will assist in producing the Users Guide
- Test plan
  - include tests that address both pipeline performance and scientific validity
- After acceptance of the instrument, the software will be configuration controlled as described in the SOFIA Science Project Software Management Plan.

Preferences/Guidelines

- Python or IDL preferred
- Open source code preferred
- Version controlled with SMO included
- Separable reduction steps, with well-defined APIs, which generate intermediate products
- SI team must provide detailed calibration plan
- Attention to keywords in FITS headers
  - Processing delayed and instrument control software required to update if changes are made

SOFIA Generation 3 Instruments: Airworthiness

Maureen Savage

Airworthiness Concerns

- Anything that can cause injury to personnel or aircraft equipment
- Anything that can cause a fire
- Commands/interactions between systems that can cause a hazard
- Anything that affects the aircraft pressure boundary
- Foreign Object Debris (FOD) and equipment
- Pressure Systems
- Cryogens
- Toxic Substances
- Radiation, both ionizing and non- ionizing

Science Instrument Airworthiness Team (SIAT)

- Tim Krall – AFRC Operations Engineering, (SIAT Chairman)
- Tony Chen – AFRC Structures Engineering (science instrument structural integrity)
- Jeff Williams – Safety & Mission Assurance (hazard reports, instrument systems)
- Jeff King – AFRC Safety & Mission Assurance
- John Marcrum – AFRC Safety & Mission Assurance, SOFIA Program Safety Officer
- Brennan Riley – AFRC Safety & Mission Assurance (hazard reports, System Safety Working Group
- Kim Ennix-Sandhu – AFRC Safety & Mission Assurance
- James Milsk – AFRC Systems Engineering (instrument electrical systems analysis)
- Jim Mills – AFRC Operations Engineering (instrument electrical systems analysis)
- Richard Wong – AFRC Pressure Systems Manager
- Mike Collie – AFRC Quality Inspection
- Dave Walker – AFRC Quality Assurance (SIAT + Gary Pacewitz/ Brandt Grimes)
- Jonathan Brown –SOFIA Systems Engineering & Integration, AFRC Safety

SI Developer's Facility

SOFIA S&MA

- Assists NASA to create/mod contract
- Works with SE&I & SIAT to verify req'ts listed in Verification Plan or in SI System Spec
- Reviews S&MA-related plans & ADP
- Coordinates Gov't Mandatory Inspection Points (GMIPs) with contractor/grantee
- Witnesses GMIPs
- Coordinates items with AFRC B703 Facility Safety which would impact B703 Safety
- PDR, CDR, Pre-Ship Review member
- Participate in site visits, if requested
- Monitors and audits contractor/grantee's QA process
- Works with SI team to get SI Hazard Reports (HRs) approved by SSWG

SIAT

- Reviews SI airworthiness documentation
- Participates in Airworthiness site visits
- Provides SI airworthiness certification
- Verify req' ts listed in Verification Plan & SI System Spec as SIAT-verified
- PDR, CDR, & Pre-Ship Review member
- Gov' t QA oversight/witness for design characteristics classified Safety Critical

AFRC Building 703

SI Labs

SOFIA S&MA

- S&MA sign-off authority on procedures
- Primary QA stamp-off authority on work
- Approves procedure redlines

SIAT

- Verify req'ts listed in Verification Plan & SI System Spec as SIAT-verified

Aircraft

SOFIA S&MA

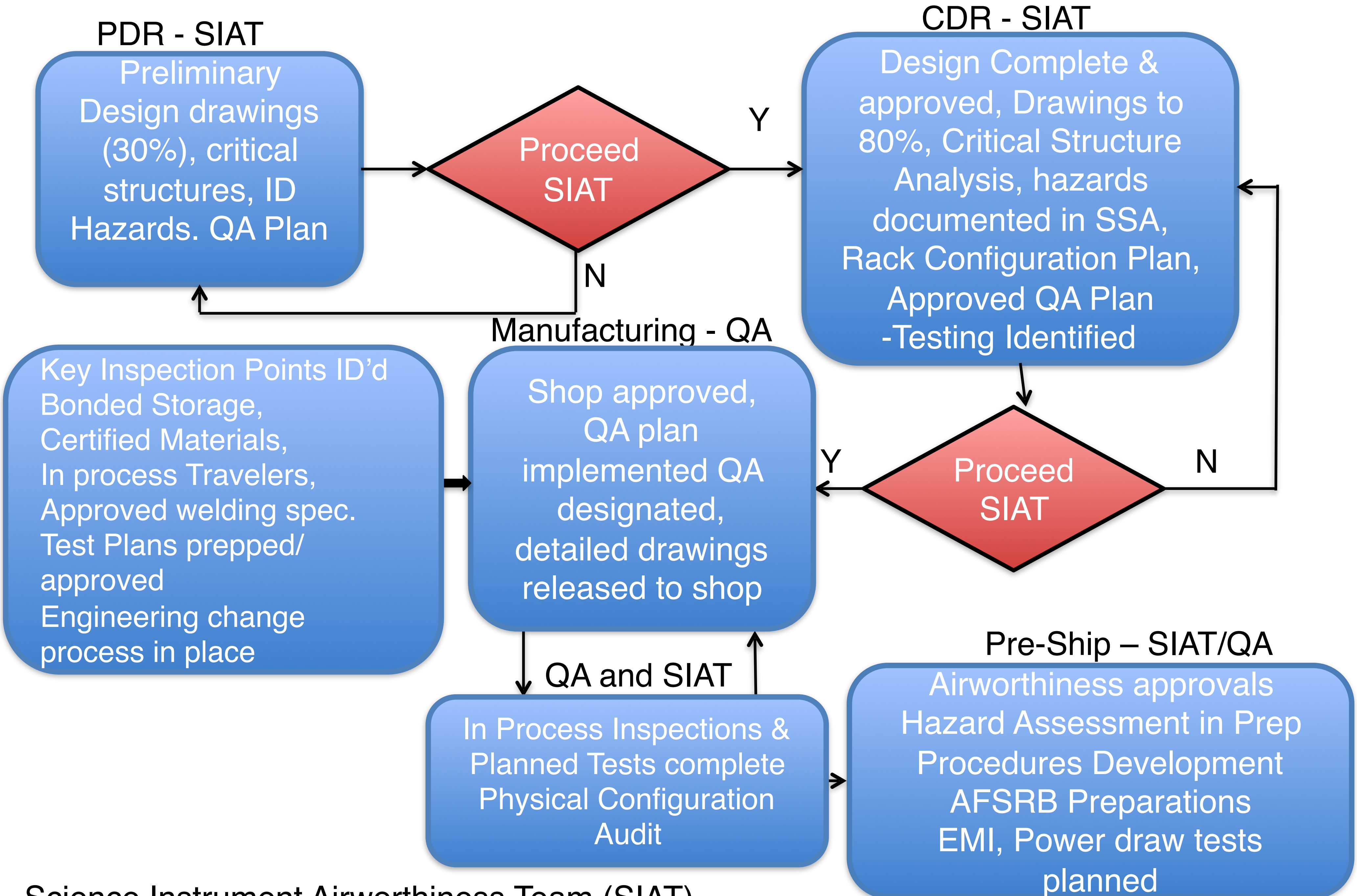
- S&MA sign-off authority on all procedures
- QI/QA stamp-off on work
- Mishap Response
- Lead for aircraft hazards (SSWG)
- Monitor hazardous operations

SOFIA S&MA

- Impound items and assist AFRC/ ARC during a Mishap Response

AFRC B703 Facility Safety

- Reviews safety-related procedures
- Audit facility for safety



Science Instrument Airworthiness Team (SIAT)
Quality Assurance (QA)

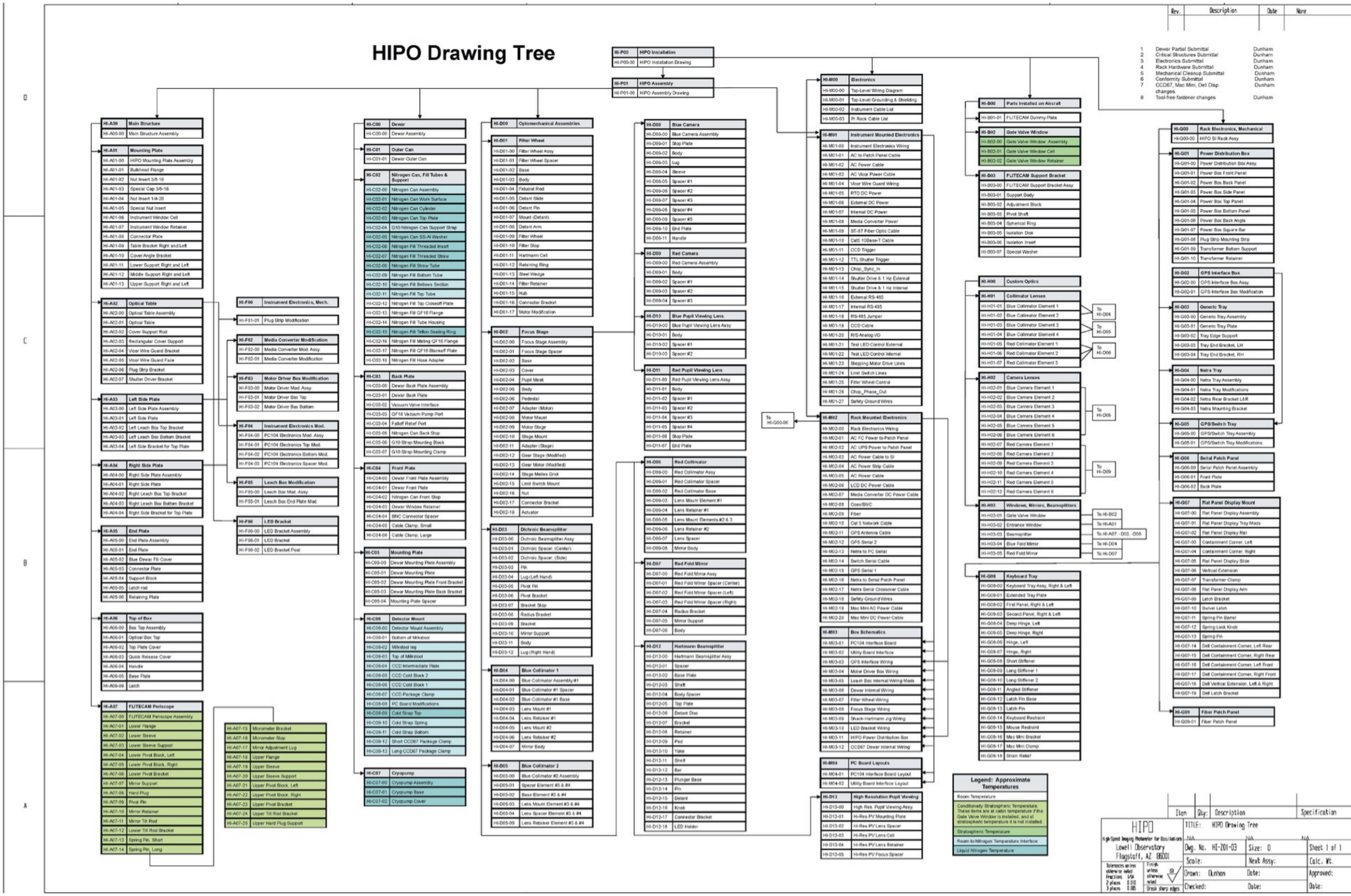
Airworthiness Deliverables

Drafts @ PDR, Update @ CDR, Final @ Pre-ship

- Drawing Package ,
  - Drawing Tree, Drawing List
  - Assembly drawings
  - Identification/Drawings of Critical Safety Items (CSI)
- Quality Plan
- Electrical Systems Report
- Instrument assembly and structural analysis report
- PI Rack and CW Rack Reports
  - equipment layout,
  - CG analysis
- System Safety Assessment and assistance with Hazard Reports
  - Relief devices, burst disks, pressure analysis
  - Hazard reports developed by SIAT/SOFIA System Safety Working Group with Instrument development group assistance
- Pressure Test Plan and Resulting Report
- Certification documents for safety items

Mechanical Design Package

- **Critical structures List**
- Assists in describing the instrument design from a safety perspective.
- Examples are design dependent but can include: TA Flange interface, electronics box attachments to cryostat, cryogen reservoir assemblies, pressure boundary, optics bench,
- **Drawing Tree –**Clarifies load structure and load path of instrument
- **Drawing List** – lists all drawings to be included in configuration management process
- **Drawings** - utilize relevant numbering system for drawing management
  - Instrument cryostat, reservoirs, optics bench and internal components
  - Instrument PI Rack – configuration drawings for final installation design
  - Instrument CW Rack – Weight and CG critical, final as installed drawings
  - Cable drawings – included in weight budget. See electrical guidelines
- **Analysis**
  - Center of Gravity analysis, and mechanical design loads analysis for Margins of Safety (MS>0 OK) - See 2028 specification for guidelines.
  - PI rack turning moment based on the as installed center of gravity.


HIPO Drawing Tree
HI-P00 HIPO Installation
HI-P01 HIPO Assembly
HI-A00 Main Structure
HI-C00 Dewar
HI-D00 Optomechanical Assemblies
HI-M00 Electronics
HI-B00 Parts Installed on Aircraft
HI-H00 Custom Optics
HI-G00 Rack Electronics, Mechanical
Legend: Approximate Temperatures

HIPO Drawing List – Partial

HIPO Drawing List Document No. HI-Z01-02 Rev. 5.11 - 3/24/2014

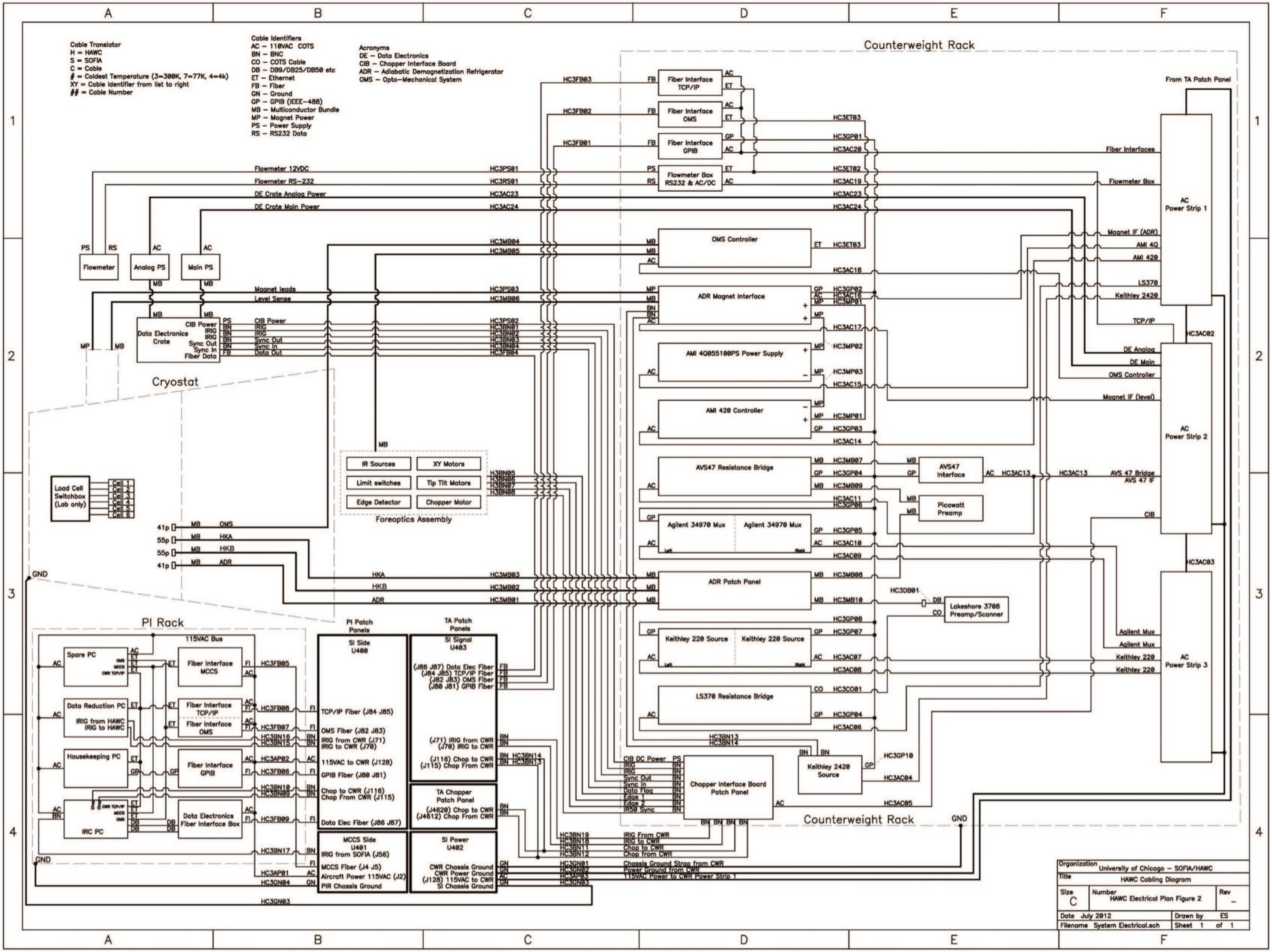
Drawing Number	Rev. No.	ECO Rev.	Number of Sheets	Drawing Title	From Assembly	Drawn By	Checked by	Checked Date	Approved by	Approved Date
A00 - Main Structure										
HI-A00-00	2		1	Main Structure Assembly	HI-P01-00	Dunham	Nye	9/28/05	Dunham	9/28/05
A01 - Mounting Plate										
HI-A01-00	2		2	HIPO Mounting Plate Assembly	HI-A00-00	Dunham	Nye	5/6/11	Dunham	5/6/11
HI-A01-01	2		1	Bulkhead Flange	HI-A01-00	Nye	Nye	9/28/05	Dunham	9/28/05
HI-A01-02	1		1	Nut Insert 3/8-16	HI-A01-00	Nye	Dunham	11/22/02	Dunham	11/22/02
HI-A01-03	2		1	Special Cap 7/8-12	HI-A01-00	Nye	Nye	9/28/05	Dunham	9/28/05
HI-A01-04	1		1	Nut Insert 1/4-20	HI-A01-00	Nye	Dunham	11/22/02	Dunham	11/22/02
HI-A01-05	2		1	Special Nut Insert	HI-A01-00	Nye	Nye	9/28/05	Dunham	9/28/05
HI-A01-06	1		1	Instrument Window Cell	HI-A01-00	Nye	Dunham	11/22/02	Dunham	11/22/02
HI-A01-07	2		1	Instrument Window Retainer	HI-A01-00	Nye	Nye	9/28/05	Dunham	9/28/05
HI-A01-08	2		1	Connector plate	HI-A01-00	Nye	Nye	9/28/05	Dunham	9/28/05
HI-A01-09	1		1	Table Bracket Right and Left	HI-A01-00	Nye	Dunham	11/22/02	Dunham	11/22/02
HI-A01-10	1		1	Cover Angle Bracket	HI-A01-00	Nye	Dunham	11/22/02	Dunham	11/22/02
HI-A01-11	2		1	Lower Support Right and Left	HI-A01-00	Nye	Nye	9/28/05	Dunham	9/28/05
HI-A01-12	1		1	Middle Support Right and Left	HI-A01-00	Nye	Dunham	11/22/02	Dunham	11/22/02
HI-A01-13	2		1	Upper Support Right and Left	HI-A01-00	Nye	Nye	9/28/05	Dunham	9/28/05
A02 - Optical Table										
HI-A02-00	3		1	Optical Table Assembly	HI-A00-00	Dunham	Nye	3/11/08	Dunham	3/11/08
HI-A02-01	2		3	Optical Table	HI-A02-00	Nye	Nye	9/28/05	Dunham	9/28/05
HI-A02-02	3		1	Cover Support Rod	HI-A02-00	Darwin	Nye	5/6/11	Dunham	5/6/11
HI-A02-03	1		1	Rectangular cover support	HI-A02-00	Darwin	Nye	11/22/02	Dunham	11/22/02
HI-A02-04	1		1	Vicor Wire Guard Bracket	HI-A02-00	Darwin	Nye	11/22/02	Dunham	11/22/02
HI-A02-05	2		1	Vicor Wire Guard Face	HI-A02-00	Darwin	Nye	9/28/05	Dunham	9/28/05
HI-A02-06	1		1	Plug Strip Bracket	HI-A02-00	Darwin	Nye	11/22/02	Dunham	11/22/02
HI-A02-07	2		1	Shutter Driver Bracket	HI-A02-00	Darwin	Nye	9/28/05	Dunham	9/28/05
A03 - Left Side Plate										
HI-A03-00	2		1	Left Side Plate Assembly	HI-A00-00	Dunham	Nye	9/28/05	Dunham	9/28/05
HI-A03-01	2		1	Left Side Plate	HI-A03-00	Nye	Nye	9/28/05	Dunham	9/28/05
HI-A03-02	2		1	Left Leach Box Top Bracket	HI-A03-00	Darwin	Nye	9/28/05	Dunham	9/28/05
HI-A03-03	2		1	Left Leach Box Bottom Bracket	HI-A03-00	Darwin	Nye	9/28/05	Dunham	9/28/05
HI-A03-04	2		1	Left Side Bracket for Top Plate	HI-A03-00	Darwin	Nye	9/28/05	Dunham	9/28/05

Electrical Package

- Overview of electronics connections – PI Rack to CW Rack to Instrument
  - Power budget and Supplied (UPS vs Frequency generated) Power use
  - Power draw and surge measurements (just prior to pre-ship)
  - EMI analysis and test plan (on board A/C)
  - Compliance with FAA/NASA stay out frequencies with instrument
    - Part of the SI Developers Handbook

- Drawings to include
  - fusing, and box to box interconnects
  - Detailed cable drawings
  - Cable size commensurate with power load
  - Cable jacket fabricated of Tefzel or other approval aircraft material
  - Utilize appropriate fusing for each separate box component

- Use of Government industry data exchange program (GIDEP) in selection of electronic parts is recommended



Cable Translator
H = HAWC
S = SOFIA
C = Cable
# = Coldest Temperature (3=300K, 7=77K, 4=4k)
XY = Cable Identifier from list to right
= Cable Number
Cable Identifiers
AC – 110VAC COTS
BN – BNC
CO – COTS Cable
DB – DB9/DB25/DB50 etc
ET – Ethernet
FB – Fiber
GN – Ground
GP – GPIB (IEEE-488)
MB – Multiconductor Bundle
MP – Magnet Power
PS – Power Supply
RS – RS232 Data
Acronyms
DE – Data Electronics
CIB – Chopper Interface Board
ADR – Adiabatic Demagnetization Refrigerator
OMS – Opto-Mechanical System
Counterweight Rack
Cryostat
PI Rack
Foreoptics Assembly
PI Patch Panels
TA Patch Panels
Organization University of Chicago – SOFIA/HAWC
Title HAWC Cabling Diagram
Size C
Number HAWC Electrical Plan Figure 2
Rev –
Date July 2012
Drawn by ES
Filename System Electrical.sch
Sheet 1 of 1

Manufacturing Guidelines

- Certified materials for all critical structures and flight fasteners
  - Some Commercial Off the Shelf (COTS) acceptable
  - Some safety equipment (burst disks/relief devices) will be delivered with certification documents and failure analysis reports.
  - Bonded storage for certified material
- Provide in process manufacturing travelers
- QA Plan implemented at developers institution and manufacturing location
- QA system in place for in – process inspections (comparison as built to drawings)
  - Key inspection points determined by NASA QA
- QA personnel may be provided by NASA/SIAT/SRM&QA
- Configuration control and engineering change process for approved designs
  - Submit design changes to SIAT as necessary during manufacturing
  - Certified welders and approved welding specifications
  - Post welding inspections, dye penetrant testing (depending on criticality)

- Final QA and inspection to as built drawings – by NASA
  - Physical configuration audit (PCA). Most of this work will be done as part of the manufacturing inspection process

Quality Plan

- A) How development teams existing practices will be tailored for this project
- b) Documented plans and procedures that need to be developed for key design, build and verification activities.
- c) Technical standards and specifications chosen by the Instrument Team
- d) Schedule for key requirements, design and readiness reviews (e.g., PDR, CDR, Pre-Ship)
- e) Hardware and software development process that to be monitored and controlled by the Instrument Team
- f) Definition of planned components, assemblies and systems inspections and verification (PCA)
- g) Identification of new or upgraded fabrication, assembly, inspection, test, non-destructive examination (NDE) or measurement methodology or equipment are necessary
- h) List of fabrication processes that need to be qualified as capable of achieving requirements
- i) Key conformity records generation, compiling and protection to ensure their availability throughout the anticipated life of the science instrument
- j) Identification of anticipated outsourcing / acquisitions of materials, technical services, special processes

System Safety Analysis

- Functional Hazard Analysis
  - Identify hazards with each functional system
    - Cryogen system
    - Electronics (high voltage)
    - Calibration gasses (not sure this is real now)
    - Software (if necessary)
- Failure Modes and Effects Analysis
  - Anticipate failures and determine effects on personnel, and aircraft
- Fault Tree for safety devices
  - Fault tree for safety devices
- Hazard Analysis to be done with NASA Safety Team
  - Translate instrument FMEA/FHA into hazard analyses that comply with NASA Hazard reporting format.
  - Ensures safety personnel understand hazards and mitigations

Airworthiness Reviews and Inspections

- Preliminary design review (PDR)
  - Designs, preliminary analysis and initial identification of critical safety items
- Prior to cutting metal – Critical Design Review (CDR)
  - Manufacturing Drawings, and final analysis of critical structures/parts
- Pre-ship Documentation Requirements
- Time Line 60-90 days for the SIAT review of documents
- Final Deliverables and documentation required prior to pre-ship
  - Drawings + drawing list/tree
  - Electronics -
  - Safety -
  - Analysis
  - Configuration Management

- Fabrication
  - Welding – certified process and personnel
  - In process inspections/testing as necessary
  - Configuration control/management during manufacture

SI Airworthiness Review Evaluation Criteria

Tim Krall
SOFIA Science Instrument Airworthiness Team Chairman
AFRC Flight Operations Engineering

1 February 2016

What is Airworthiness?

- Airworthiness concerns safety of onboard crew and aircraft

- The following are areas that relate directly to airworthiness
  - Items that cause personnel injury
  - Items that cause a fire
  - Commands by one system to other systems that result in hazardous conditions
  - Items that affect the aircraft pressure boundaries
  - Foreign Object Damage (FOD) and equipment security
  - Pressure systems
  - Cryogens
  - Toxic substances
  - Radiation (ionizing/non-ionizing)

Who is this SIAT?

- Science Instrument Airworthiness Team (SIAT)
- Armstrong Flight Research Center personnel
- Comprised of individuals from the following specialties:
  - Operations Engineering
  - System Safety
  - Electrical Engineering
  - Structures Engineering
  - Quality Assurance
  - Cryogenic Pressure Systems

References & Areas of Evaluation

- Design criteria are found in the SOFIA Science Instrument System Specification (SOF-AR-SPE-SE01-2028) with guidance in the SOFIA Science Instrument Developer's Handbook (SCI-AR-HBK-OP03-2000)

- Areas of specific consideration during the review team evaluation
  - System Safety Analysis
  - Structures
  - Pressure Vessels
  - Electrical
  - Radiation
  - Software

SOFIA Stratospheric Observatory for Infrared Astronomy

SIAT Responsibilities

- Regular meetings with team members for updates of science instrument changes and airworthiness documentation review
- Participation in various review meetings:
  - Technical Interchange Meetings (TIM)
  - Preliminary Design Review (PDR)
  - Critical Design Review (CDR)
  - Pre-Shipment Review
  - Technical Briefing
  - Pre-Installation Review
- Review and concurrence of key test plans: cryostat pressure vessel, vent hardware proof tests, others…
- Witnessing key tests to provide concurrence with test conduct and results

SIAT Responsibilities

- Review and technical concurrence with analysis determining cryostat maximum pressure and vent sizing for highest mass flow rate due to worst case heat transfer
- Review of cryostat pressure relief device certifications and decisions of certification requirements based on planned operation
- Review of structural analyses for critical hardware to verify adequate structural margins of safety for ultimate aircraft loads
- Review of electrical system and drawings to verify adequate grounding, proper switching and fusing to aircraft electrical power sources, and appropriate command and date interfaces to MCCS

SIAT Responsibilities

SOFIA Stratospheric Observatory for Infrared Astronomy

- Review of science instrument pressure boundary to determine acceptable responses for cabin pressure breach
- Review of safety documentation with independent assessment of risks for the following typical hazards:
  - Cryostat Over-Pressure
  - Structural Failure
  - Electrical Shock or Fire
  - Cabin De-Pressurization
- Review of documentation for quality assurance concerns especially cryostat tank welds, pressure relief device certifications, and critical faster certifications
- Concurrence with any non-compliant aspects of the science instrument for which a waiver may be justified

Airworthiness Process

- SIAT provides initial review of instrument design, hazards, mitigations, and guidance for development of operational restrictions or procedures
- Airworthiness Recommendation Letter
  - Written by SIAT members with content reviewed and approved by science instrument team Principle Investigator and others
  - Serves as initial recommendation to AFRC Airworthiness & Flight Safety Review Board (AFSRB)
- Technical Briefing
  - Formal introduction of science instrument to AFSRB through presentation and dialogue
  - Occurs within 1-2 weeks of science instrument inaugural flight

SOFIA Stratospheric Observatory for Infrared Astronomy

Demonstrating Airworthiness

Low Risk

Design or Test to referenced specification

- OR -

Design or Test to equivalent standard

(this must be demonstrated/verified equivalent)

- OR -

Contact the airworthiness team for mitigation

(additional….

design, analysis, procedures, operational

restrictions, testing, risk/hazard assessment

Then…

waiver and risk/hazard acceptance)

Increased Risk

Waiver Process

- Requests for waiving a requirement must examined by the SIAT (who may be able to offer an alternative means of meeting the requirement without need for a waiver)
- Waivers are reviewed, accepted, and approved through the Observatory Configuration Control Board (OCCB)
- Waivers specify
  - The requestor
  - Requirement to be waived
  - Justification for not meeting the requirement
  - Period for which the waiver will be active if requirement is to eventually be satisfied
- Waivers to AFRC processes are presented to the Airworthiness and Flight Safety Review Board for final acceptance

Closing Thoughts

- Open communication is key to the successful navigation of this process
- If you have questions correspond with the Science Instrument Airworthiness Team (SIAT) members - CALL or WRITE!!!

Armstrong B703 Science Facilities & Laboratory Operations

Zaheer Ali, SOFIA Lab Supervisor

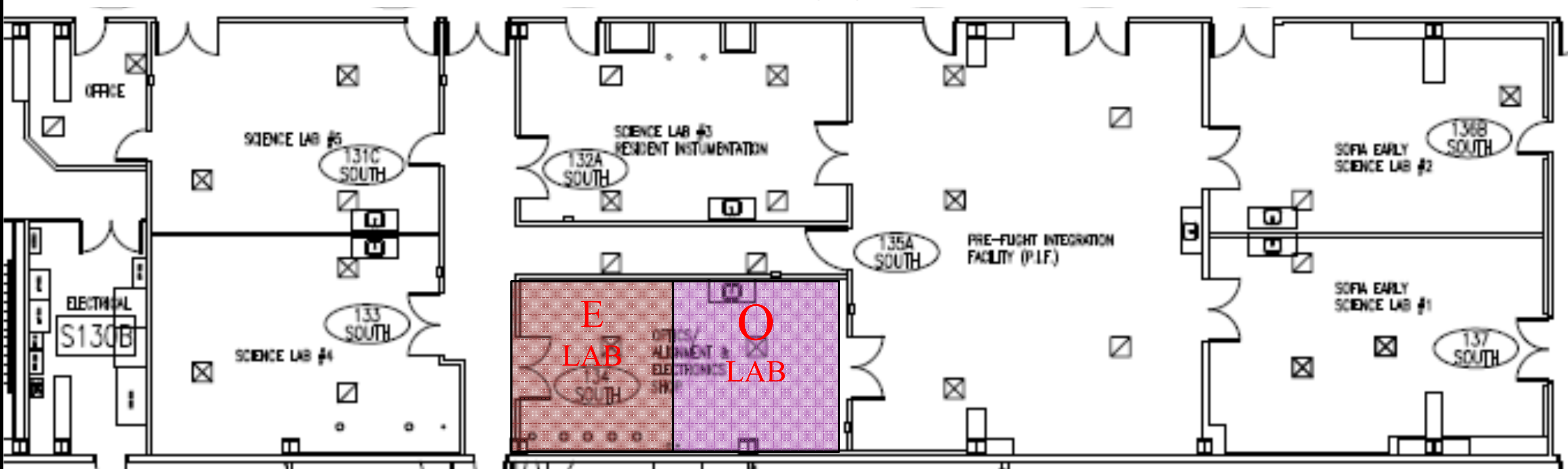
SOFIA 3d-gen Science Instrument Kickoff Meeting

2-3 February 2016

Armstrong B703 facilities are capable of science instrument preparation, maintenance, and repair.

Summary

- The SOFIA Science Labs are comprised of dedicated science instrument (SI) labs, an electronics shop, optics lab, and the Pre-Flight Integration Facility
- Dedicated SI labs are for standard operations including cryogen fills, testing, and basic maintenance as well as more detailed work
- The electronics shop is prepared for electronic work from making cables to board level repairs
- The optics lab is a clean space where sensitive components can be handled
- The Pre-Flight Integration Facility (PIF) is a general use area that also houses the telescope alignment simulator
- Additionally, SOFIA Science IT operates and maintains the Software In the Loop Lab (SIL), which is where instrument software can be tested against the SOFIA TA GUI.
- A variety of ancillary equipment is available for support, including vacuum pumps and hardware, as well as measurement and test equipment.



Each instrument is assigned a science lab that has storage and workspace

- Each lab has separate access control
- Two standard power types available: 60 Hz, 120V 20A or 230V 30A
- A section of each lab has a ceiling height of 12 ft.
- Temperature control is independent to each room and can maintain 68 degrees
- Air exchanges are sufficient for one cryogen fill at a time
- ESD dissipative floors throughout lab areas
- GPS and Ethernet in each lab

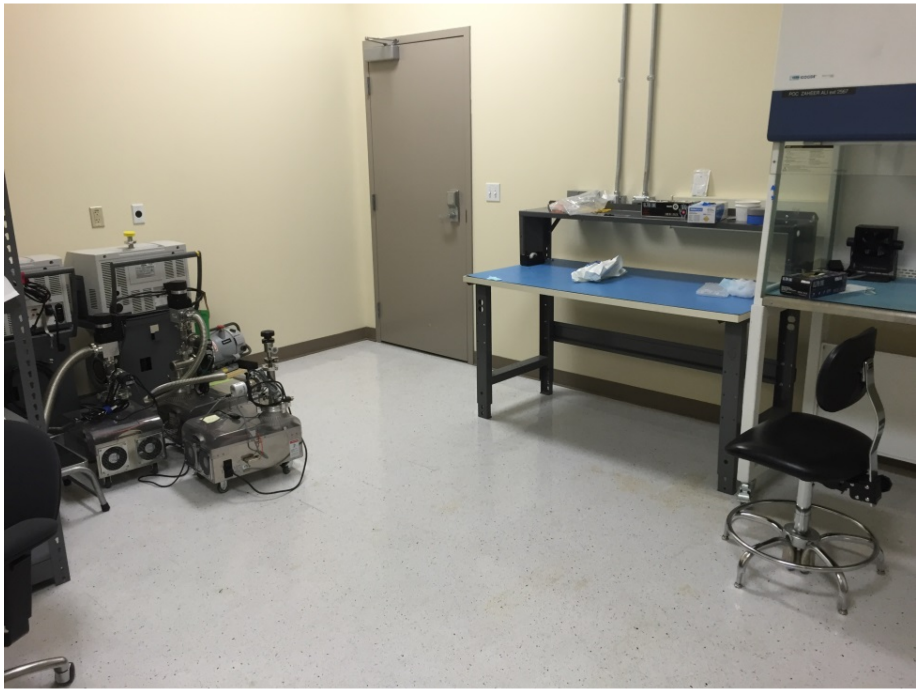
Lab 4: FIFI-LS

The electronics shop has both manufacturing and testing capability

- ESD certified benches
- Cable and harness manufacturing capability
- Measurement and test capability:
  - High bandwidth scopes
  - Spectrum analyzer
  - Function generators
  - High precision DMM
  - Digital delay/ pulse generators

The optics lab can become a class 100k or better clean room at need

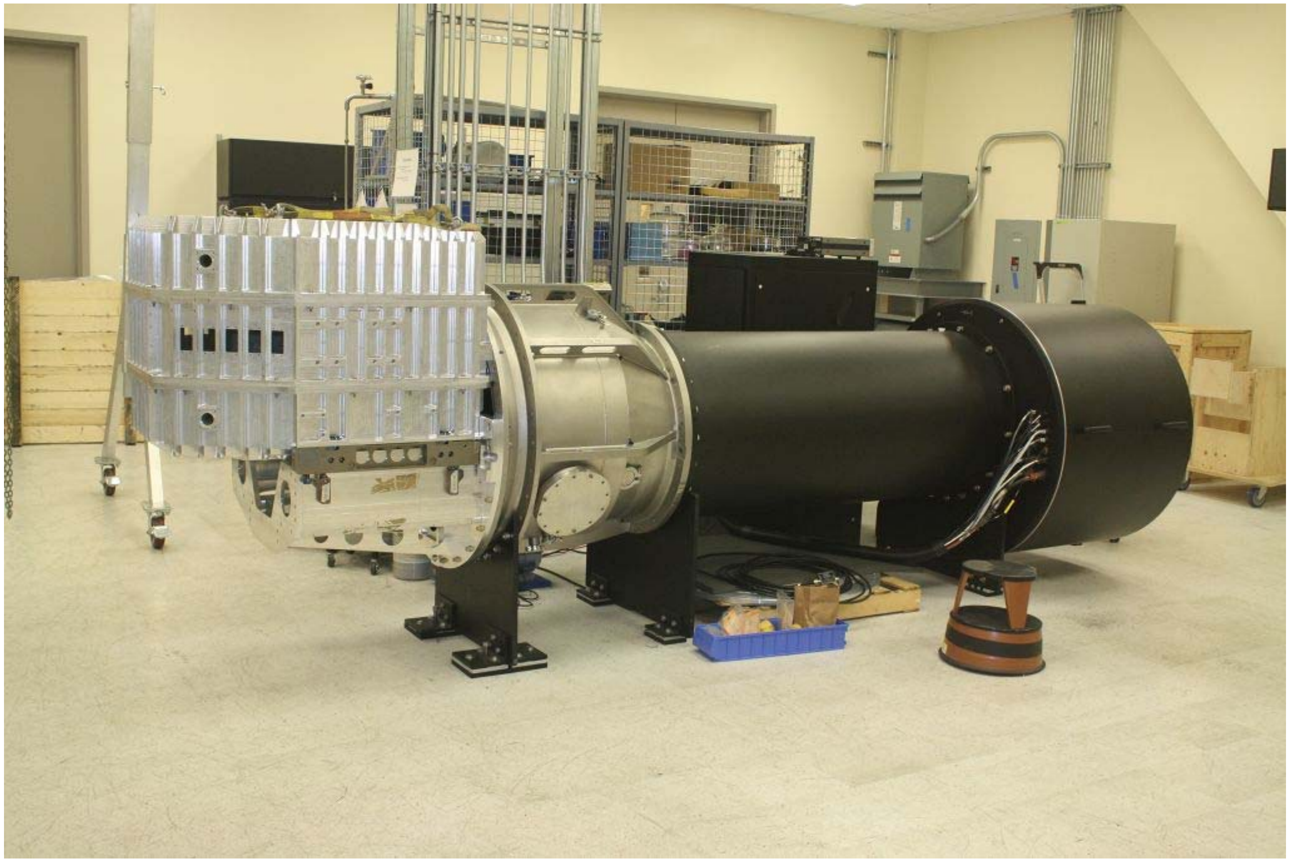
- We can "go clean," to do sensitive work
- HEPA filtered air with a hard lid
- N2 box storage will be added
- ESD certified ionized flow bench available
- Open area for disassembly and internal SI work
- Fiber cleaning and analysis tools



The Pre-Flight Integration Facility is a multi-use area with ample space for heavy work

- ESD certified benches
- The Telescope Assembly Alignment Simulator
- Temporary cryogen storage
- PPE, and general work supplies
- Sink
- Document storage
- Compressed Air
- Full network connectivity

The Telescope Assembly Alignment Simulator



- IMF:
  - Replica of TA flange
  - Vacuum capable
  - Has pressure coupler flange at gate valve
- Focused Chopped Light Source
  - PID controlled black body source with multiple apertures
  - Adjustable focus to SI
  - Chopper wheel
- Large Chopped Hot Plate
  - Simulates pupil viewing mode for secondary mirror imaging
- Small Chopped Hot Plate
  - SOFIA beam size plate
- Can go dry
- Located with convenient access to network
- Compressed air

There is a variety of ancillary ground support equipment and supplies are available

- A-frame gantry hoist
- Multiple cherry picker lifts
- Turbo and rough pumps
- Multiple tool sets available
- Logistics equipment
- Vacuum hardware
- Chemicals as needed
- Gases and cryogens
- UPS and power converters from 60 Hz -> 50 Hz

SOC-SIL

- USRA IT has set up several connection to the SI-labs to give the SI teams the ability to simulate the aircraft experience. This capability allows the SI to perform dry runs of their software and hardware against simulated aircraft systems to ensure that their SI will integrate with the aircraft platform.
- Observation modes, AORs, and flight plans can all be tested against the SIL with the assistance of the mission operations team (TOs, MDs, Flight Planners).
- This capability can be set up in minutes and can allow for SI labs to SOC-SIL connections or even SI-labs to Aircraft connections.
- Bi-directional connection from SOC-SIL to SI Labs currently exists and is tested
- Bi-directional connection from SI labs to aircraft currently exists and is tested
- Bi-directional connection from HIL's to SI Labs currently exists and is tested
- Remote connections to the SI's while they are in the lab currently exists, but prior notification and set up may be required (up to two weeks lead time to establish this connection)

- **B703 Science IT lead is Shawn Granen: sgranen@sofia.usra.edu**

A few notes on operations

- Documentation
  - Lab operations at B703 require a certain level of documentation and procedure: many documents can be created by altering existing SI operations documents
- SI to aircraft installations
  - Installation methods are developed using the TAAS and other lab tools; once on board procedural requirements apply
- Network connectivity
  - 2 types of networks: “hotel” and experimenters’
  - Multiple permutations exist: lab to SIL, lab to aircraft, aircraft to SIL
  - A pipe can be opened to the home institution; only the aircraft is barred from this
  - Network can be supplied to the aircraft during line operations
- Maintenance and Engineering staff have a full complement of engineering, SI development, cryostat design, and detector engineering skills

SI-MCCS Tier Testing

E. Moore, USRA

SI – MCCS Tier Tests

- A series of tests designed to support SI – MCCS integration
- Broken into “Tiers” of increasing complexity
- Tiers 1 – 3
  - SI development teams work with SOFIA software staff to develop / test Tiers 1 – 3.
  - Should be done well in advance of the Pre-ship review.
- Tiers 4
  - Work with Mission Operations / Instrument Scientist teams to develop / test Tier 4 (Observing Scenarios)
  - Should be completed by Pre-ship review

SI Tier Testing (Tiers 1 – 3)

- Tier 1 – Test Basic Connectivity (successful / error cases)
  - Test Creating a Session(s) / Logging In
    - Test that the SI can create a session (via tcp/ip) and log into the MCCS (one or multiple times)
    - Test that the SI can reflect that they are connected
    - Test log out
  - Test Login Under Error Conditions (either MCCS or SI)
    - Attempt to create a session when the MCCS is not running
    - Attempt to create a session using incorrect host/port
    - Attempt to login using an incorrect user/role
    - Create a successful session/login and then kill MCCS

SI Tier Testing (Tiers 1 – 3)

- Tier 2 – Mission Data Handling
  - Verify SI Data Interface XML
    - Work with Software team / Instrument Scientist to create the <si>_data.xml file (required to define an instrument in the MCCS). File contents defined in MCCS-SIO4 (SOF-DA-ICD-SE03-052):
      - x/y pixel scale factor
      - x/y pixel separation
      - x/y pixel min and max
      - Etc
    - Verify file can be read by MCCS
  - Accessing Housekeeping Data / Creating valid FITS file
    - Verify that the SI can access MCCS housekeeping (HK) data in support of routine instrument operation including:
      - Display to user via SI interface
      - Correctly populate relevant FITS header keywords (defined in the DCS-ICD FITS keyword table)

USRA

SI Tier Testing (Tiers 1 – 3)

- Tier 3 – SOFIA Command Language (SCL) Command Handling
  - Verify SCL Command Handling
    - Format / send SCL commands correctly
      - Attempt to send ALL SCL commands the SI will use in Tier 4
    - Handle success response
    - Change state or display information to user as appropriate
    - Test scripting capability
  - Verify SCL Command Error Handling
    - Demonstrate that the SI can handle various SCL error responses and provide useful feedback to the SI user (on screen, in scripts etc)

SI Tier Testing (Tier 4)

- Tier 4 – Observing Scenarios
  - Work with Mission Operations / Instrument Scientist teams to develop / test all observing scenarios relevant to routine science operations:
    - TestTweak
    - TestSMAFocus
    - TestChopNod

System Integration Labs (SIL)

- Testing will occur is System Integration Labs
  - 3 SILs available for remote SI login (2 at Ames, 1 at Palmdale). SILs contain:
    - MCCS
    - TA Simulator
    - AC Simulator

- Useful references
  - MCCS_SI_04 (SOF-DA-ICD-SE03-052)
  - SCL Users Manual (SOF-DA-MAN-OP02-2181)
  - DCS ICD [contains keyword dictionary] (SCI-US-ICD-SE03-2023)
  - Wiki page of previous Tier Tests

SI Dev Points of Contact

- NASA SI Development Team
  - Mark McKelvey, *SI Development Manager* (mark.e.mckelvey@nasa.gov)
  - Maureen Savage, *USRA SI Dev Manager* (msavage@sofia.usra.edu)
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- Palmdale Mission Operations Team
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