SOFIA Science Instrument Development Process and Deliverable Requirements

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-	9/12/2018	Initial Release	OCCB OCCB-CCR-1482

Contents

1 Introduction

This requirements document applies only to Stratospheric Observatory For Infrared Astronomy (SOFIA) Science Instrument (SI) development projects managed by the SOFIA Program.

SI developers shall comply with all of the processes and deliverables defined in this document. In addition to the physical instrument and the associated hardware and software that will be delivered, SI developers are also required to provide documentation to prove the instrument has met the requirements defined in the *SOF-AR-SPE-SE01-2028, SOFIA Science Instrument System Specification,* and SOFIA SI Interface Control Documents (ICDs).

Requirements listed in this document are applicable from Key Decision Point (KDP) A, through completion of the Legacy Science Program (LSP).

2 Process Requirements

The SI developer is required to comply with the NASA and SOFIA processes defined in this section. These process requirements apply to three specific areas of focus: project management, airworthiness & ground safety, and mission assurance.

2.1 Project Management Process Requirements

Table 2-1 lists the processes the SI developer is required to follow, to support SOFIA processes and life cycle reviews needed for the SOFIA team to evaluate the Science Instrument and associated deliverables.

Table 2-1: Project Management Process Requirements for SOFIA SI Development Project

#	Requirement	Rationale
P1	The SI developer shall report request to waive or deviate from SOFIA requirements to the SOFIA SI Development Manager prior to exercising any waiver and/or deviation.	*If the SI developer requests a deviation or wavier to the SOFIA requirements they must first coordinate with the SOFIA SI Development Manager. The SOFIA SI Development Manager, will then coordinate the request with the rest of the SOFIA program.*
P2	A quality assurance plan, closed-loop problem reporting, corrective action, and configuration management are required of the SI developer.	*The SI developer is responsible for tracking, reporting, resolving, and controlling issues that arise during the SI development process. Controlling the configuration of hardware, software, and documentation ensures consistency among physical and logical assets during SI development. How the SI developer plans to meet these expectations during the project are to be documented in a Quality Plan, produced and delivered by the SI developer.*

#	Requirement	Rationale
P3	SI developer shall lead, including acting as review chair, the following reviews. - Initial Formulation Review - Final Formulation Review	*The Initial Formulation Review supports KDP B and is the review of requirements of the system and subsystems, and the initial review of the SI design. The Final Formulation Review supports KDP C, and is the final review of the design before manufacture of the SI begins. Expectations for these reviews are further detailed in Appendix B.*
P4	SI developer shall participate in and support the following SOFIA Program led reviews. - Pipeline Readiness Review - Pre-Shipment Evaluation - Pre-install Review - Pipeline Acceptance Review - Operations Acceptance Review	*The pipeline reviews ensure the science data pipeline has been completed, and that it is ready for processing data collected by observers. The Pre- Shipment Evaluation supports KDP D and establishes that the SI development and testing are complete enough to ship the SI to B703 at AFRC. The Pre-install review supports KDP E and establishes that the instrument works, and that it is safe to place aboard the aircraft. After the completion of all of the commissioning flights and commissioning requirements, an operations acceptance review that supports KDP F is conducted prior to the formal acceptance. After formal acceptance, the SI is made available to investigators for science. Expectations for these reviews are further detailed in Appendix B.*
P5	SI developer shall participate in and support the following SOFIA Science and Mission Operations (SMO) led reviews. - LSP Kickoff Review - LSP Review	*The primary focus of the LSP Review is to evaluate the SI provided Observing Plan for the LSP exploitation period. In addition, the commissioning plan and report will be reviewed, and the science performance will be evaluated. Integration of the SI with SOFIA operations, schedule, data pipeline plans, budget, and public affairs will also be discussed. Expectations for these reviews are further detailed in Appendix B.*
P6	SI developer shall participate in and support commissioning of the SI.	*Each new SI must be commissioned prior to making the SI available to investigators for science. The commissioning process characterizes the core performance of the FSI and includes, but is not limited to, completion of a commissioning plan, completion of the commissioning flight tests per the commissioning plan, and documenting the results of the commissioning in an SI commissioning report.*
P7	SI developer shall have a risk management process that report risks to SOFIA Program as part of status reporting.	*Risk management strategies are used to identify the projects opportunities and threats. To ensure project success, the SI developer must define how potential risks will be handled, so problems can be identified, mitigated or avoided.*

#	Requirement	Rationale
P8	The SI developer shall deliver the products listed in Table 3-0 to the SOFIA Program three weeks prior to the reviews that support the KDPs listed in Appendix B.	*Airworthiness and safety-driven requirements demand a rigorous review process for safety-critical components or subsystems. Documentation is required in order to conduct a thorough review and traceability of articles subject to airworthiness evaluation. All elements within the table are required to be delivered, with the exception of those elements for which the instrument design does not have nor use that particular design feature (e.g., no cryogen reservoir drawing is required if the instrument design does not have a cryogen reservoir). Additional drawings may be requested by the SOFIA program. The SI developer will be compensated for any additional product beyond what is listed in Table 3-0 of this document.*

2.2 Airworthiness and Ground Safety Process Requirements

Table 2-2 lists the processes the SI developer shall follow to support airworthiness evaluation and certification of the Science Instrument, as well as ground safety evaluation for the Science Instrument and associated deliverables.

Table 2-2: Process Requirements for SI Airworthiness and Ground Safety

#	Requirement	Rationale
P9	SI Pressure Vessel Systems (PVS) Qualification and Acceptance Test Plans / Procedures and test date(s) shall be pre-coordinated with the SOFIA Program at least 30 days prior to test.	*Per SE01-2028 ParID 3.5.3.3, Due to the safety critical nature of flying pressure vessels onboard aircraft, PVS Test Plans / Procedures are to be pre-coordinated with SOFIA Program SI Development team and SIAT, so plans can be evaluated to ensure the tests will be adequate to meet airworthiness requirements.*
P10	Flight components that require Acceptance or Proof testing for certification or recertification purposes shall each be labeled or tagged with a unique identifier.	*Per SE01-2028 ParID 3.5.3.3, Supports unambiguous tracking of Acceptance and Certification / Recertification status of PVS components. This includes periodic pressure testing of pressurized flexible lines, and inspection / calibration of Pressure Relief Valves (PRVs). References include; AFOP-8715.3-013, Pressure Vessels & Pressurized Systems Safety, ParID 11.2 M.*

#	Requirement	Rationale
P11	Safety Critical* Single Point Failures (SPFs) may be permitted, but shall be mitigated by use of high reliability parts, additional testing, or by other means that are deemed acceptable by the core members of the Systems Safety Working Group (SSWG). Single string and selectively redundant design approaches may be used.	*If the failure of a single part or element of the SI could potentially be hazardous to the aircraft or crew, it may be permitted, but must be mitigated. The assessment of multiple SPFs happening at the same time is not required. Single string and selectively redundant design approaches may be used. Safety critical is defined in the NASA SOFIA Science Instrument Development Decision Memorandum as:* "***Safety Critical**—a failure to meet the flight hardware or software requirements for that characteristic could cause or lead to severe injury, major damage, or mission failure if performed or built improperly, or allowed to remain uncorrected. The loss of the SI by itself does not constitute a mission failure."
P12	Personnel performing fabrication or inspection of welds on SI cryostat assemblies, and any structures listed within the SI Critical Safety Items List (CSIL), shall be trained and certified in accordance with ANSI / AWS D17.1.	*Per SE01-2028 ParID 3.10.3.1; Welds used in the SI system must be certified in accordance with NASA and aerospace industry standards. The SI developer will need to provide evidence of welder certification as part of the airworthiness review. Weld certification (including classification, analysis, and inspection) must meet airworthiness requirements.*
P13	Personnel performing fabrication or inspection of welds on SI carts and stands shall be trained and certified in accordance with ANSI / AWS D17.1, Class B.	*Per SE01-2028 ParID 3.10.3.2; Welds used in the SI cart must be certified in accordance with NASA and industry standards. The SI developer will need to provide evidence of welder certification. Weld certification (including classification, analysis, and inspection) must meet ground safety requirements.*
P14	Testing shall be conducted for verification of safety compliance as it pertains to certification for airworthiness, and critical ground support equipment.	*Testing is conducted to verify safety compliance with the airworthiness and ground safety requirements in SOF-AR-SPE-SE01-2028; SOFIA Science Instrument System Specification and SOFIA SI ICDs.*
P15	Interfaces (hardware and software) between the SI and observatory shall be verified by the SI developer with concurrence by the Program.	*Confirmation of interface requirements are necessary to ensure the SI will fit on the TA, and that the instrument can be successfully integrated on the aircraft. Verification can be achieved with testing and/or analysis.*
P16	Design shall ensure reliability under the SOFIA operational conditions, including survivability during ground transport, ground operations, and in flight. Reliability analysis may be required based on applicable safety requirements.	*The SI developer will determine the analyses needed to verify compliance with the airworthiness and ground safety requirements in SOF-AR-SPE-SE01-2028; SOFIA Science Instrument System Specification and SOFIA SI ICDs.*

#	Requirement	Rationale
P17	SI developer shall determine Quality Assurance (QA) inspection points, and in-process test points during the fabrication and assembly process.	*Ensures quality of articles subject to airworthiness evaluation, and the effective verification of product conformity to requirements. Inspections will be chosen to verify hardware was built to match the drawings, and that no workmanship issues exist. The SI developer will plan and conduct an inspection and test program that demonstrates ICD, Science Instrument System Specification, and functionality requirements are met. This test program may include subsystem tests, integrated demonstration of instrument capabilities, or individual component testing.*
P18	All run-for-record tests shall be witnessed by QA. SI developer shall provide QA support to review any in-process test procedures, and witness testing as necessary, to ensure that articles subject to airworthiness or ground safety evaluation, are not damaged, and that tests are performed as documented.	*The SI developer QA Lead will ensure that test records identify the configuration of the test unit (i.e., part / serial numbers, and revision levels), include an unambiguous Pass/Fail declaration, and include QA acceptance that the test procedure was performed as specified. Inspection and test records will be maintained, and be made available for SOFIA Program review.*
P19	Test instruments and equipment shall be certified and calibrated.	*Proof of calibration controls will be available for all equipment used to process articles and perform inspections and tests that ensure the conformity of design characteristics, which have been classified as Safety Critical. These records will be maintained and be available for SOFIA Program review. The SI developer will determine the measurements to be made and the devices necessary to verify product and process conformance to specified requirements. These devices include test hardware and software, gauges, meters, etc. Devices or software will be controlled, calibrated and verified at regularly scheduled time intervals, in accordance with a documented procedure.*

#	Requirement	Rationale
P20	The SI developer shall provide access to the SI Assembly, PI rack, CWR, instrument installation carts, and required documentation, such that a requirements and compliance verification evaluation can be performed by SOFIA program personnel prior to instrument shipment.	*The majority of SOFIA SI System Specification and SI ICD requirements compliance verification activities will be completed and closed-out before the instrument is shipped. Several weeks before an instrument's shipment to AFRC Building 703 for the first time, SE&I and SIAT will visit the SI developer's site with a SOFIA QA Representative to conduct verification of SI hardware. Verification procedures will be prepared by the reviewers prior to the visits, and will serve as formal "as-run" records of inspection, demonstration, and tests when executed. A SIAT representative will provide their assessment of the readiness of the instrument to ship. Required documentation includes only a subset of the deliverables that are listed in Section 3.0 of this document, plus any compliance/artifacts referenced in D18 - Technical Requirements Compliance Matrix that are not part of a specific deliverable.*
P21	The SI developer shall provide access to the SI Assembly, PI rack, CWR, instrument installation carts, and associated documentation, such that a Physical Configuration Audit (PCA) can be performed for each one of these items by SOFIA program personnel.	*Airworthiness and safety-driven requirements demand a rigorous and formal Verification & Validation (V&V) process that is auditable and traceable for safety-critical components or subsystems. Government Mandatory Inspection Points (GMIPs) in the form of Physical Configuration Audits (PCAs) will be performed prior to delivery of the instrument, and are required to assure quality of Safety Critical* items*. ***Safety Critical**—a failure to meet the flight hardware or software requirements for that characteristic could cause or lead to severe injury, major damage, or mission failure if performed or built improperly, or allowed to remain uncorrected. The loss of the SI by itself does not constitute a mission failure. *Associated documentation includes only a subset of the deliverables that are listed in Section 3.0 of this document, and are available at the time of the scheduled PCA.*
P22	The SI developer shall support and participate in the following SOFIA Program led tests. - EMI Test - Safe-to-Mate cable and connector test(s) - Hangar Ops. and/or Line Ops test(s)	*After the instrument is delivered to AFRC Building 703, additional integration and testing is required before the instrument can be considered airworthy, and deemed ready for installation onboard the aircraft or flight. SI developer only required to support Hangar Ops. and/or Line Ops test(s), until completion of the LSP and exploitation period.*
P23	Structural load inspections for critical lift equipment shall be performed annually.	*Inspections must be performed annually, to certify the equipment continues to be safe to use. This may include load tests for critical lift equipment such as carts, test stands, and lift points on the SI and racks.*

#	Requirement	Rationale
P24	Unique materials used by the SI developer shall be assessed by the SI developer team for application and safety with concurrence from the Program. This also applies when a known material is being used in a novel application, not originally intended for the chosen material.	*New materials need to be understood, to determine if they pose a potential hazard that might violate airworthiness. SI developers are encouraged to explore uses of new materials where they can bring improvements to the instrument performance. However, materials need to be fully understood, to determine if a material failure might endanger human lives, jeopardize aircraft structural integrity, or diminish instrument performance in any way. SI developers must be especially vigilant when choosing materials for cryogenic windows, structural cryostat elements, adhesives and lubricants, bearings and other rolling elements, and parts of the cryogen handling/processing assemblies.*
P25	The SI shall meet SI Airworthiness Certification Criteria defined in Appendix C.	*Airworthiness and safety-driven requirements demand a rigorous and formal V&V process that is auditable and traceable for safety-critical components or subsystems.*
P26	The SI developer shall support and participate in Safety coordination meetings with the SOFIA Program.	*Includes Hazard Reports (HR), System Safety Assessment (SSA), Airworthiness, etc. The SI developer will work with the System Safety Working Group (SSWG) to provide inputs to the standard set of SOFIA hazard reports, and any additional hazards identified by the team. SI developers must deliver an initial SSA and coordination meetings are required to transform these inputs into program specific SOFIA HRs. Documentation (D26 - System Safety Assessment, D54 – Inputs to SOFIA Hazard Reports) to verify mitigations will be provided and, if necessary, physical verification (P21 – Physical Configuration Audits) by NASA safety/QA representatives will be required.*

2.3 Mission Assurance Process Requirements

Table 2-3 lists the processes the SI developer shall follow to support mission assurance objectives for the Science Instrument and associated deliverables.

Table 2-3: Process Requirements for Mission Assurance

#	Requirement	Rationale
P27	Non-Safety Critical Single Point Failures (SPF) are permitted, however, the SOFIA Program will determine if impact of failure is acceptable after review of the formal hazard assessment.	*If the failure of a single part or element of the SI could potentially affect mission success or science, the SOFIA Program will determine if impact of failure is acceptable. Assessment of multiple SPFs happening at the same time is not required.*

#	Requirement	Rationale
P28	The SI developer shall provide spares for successful execution of the Legacy Science Program (LSP).	*Limited engineering modeling is permitted. SI developer will determine the need and procure the spare parts to complete the LSP exploitation period based on the proposed approach. NASA reserves the right to direct the SI developer to provide additional spares at additional cost to NASA. SOFIA program must determine the need and procure spare parts to support SI operations for when NASA assumes responsibility of the SI.*
P29	The SI developer shall execute the Legacy Science Program (LSP).	*The SI developer must complete the science identified for the LSP defined in the Instrument Concept Study (ICS) report and agreed at KDP A.*
P30	Characterization of science performance against performance requirements shall be completed during commissioning.	*The SOFIA program does not require the SI developer to provide formal verification of subsystem performance. However, characterization of the science instrument to science requirements in the ICS Report must be completed during commissioning.*
P31	The SI developer shall follow NASA Ames Research Center (ARC) Electrical, Electronic, and Electromechanical (EEE) Best Practices for SOFIA SI Development as defined in Appendix D.	*SI developer is not required to follow a NASA Electrical, Electronic, and Electromechanical (EEE) parts program, however, they are required to follow the NASA ARC EEE best practices which can help ensure project success. SI developer shall provide a Master Parts List (MPL) to the SOFIA program for the program to determine if any risks are associated with the equipment the SI developer plans to use in the design and support the Government Industry Data Exchange Program (GIDEP).*
P32	SI software shall be developed as Class D, non-safety critical software.	*SI software is not capable of issuing a hazardous command that would affect the aircraft or damage the telescope assembly (TA). However, software can directly affect mission objectives and integrity of scientific artifacts. Class D software is defined in Appendix D of NPR 7150.2B; NASA Software Engineering Requirements and Appendix A of the SOF-NASA-PLA-PM20-2011; SOFIA Software Management Plan.*
P33	Data Acquisition and SI control computer operating system shall be updated/maintained to remain secure and compatible with the aircraft network.	*The operating systems on SI computers will be updated as needed to maintain compatibility with the aircraft's network. Maintainability must be considered during design to enable standard servicing and operations.*
P34	The SI developer shall support and participate in Scientific Data Pipeline testing and evaluations.	*Supports SI data processing validation.*

#	Requirement	Rationale
P35	Deliverable design drawings and models shall be generated with the commercial license for CAD software.	*Products can be produced using any industry standard CAD software such as Solidworks, PTC Creo, Autodesk Inventor, or other application if approved by the SOFIA program. Products produced using the academic or educational editions of CAD software will not be accepted.*

3 Deliverable Requirements

There are 3 types of deliverable products for a Science Instrument (SI): Hardware, Software, and Documentation. The SI developer shall deliver the products in Table 3-0 per the schedule in the Appendix A.

The SOFIA program will provide some document templates and content synopses to the SI developer to assist the SI developer in developing the documentation product.

In this table the term "drawing" means 2D drawings or 3D models.

Table 3-0: Deliverable Requirements for a SOFIA SI

#	Deliverable Requirement
	HARDWARE
D1	**Science Instrument Assembly** Complete cryostat assembly, which mounts to the Telescope Assembly. Includes, but is not limited to, the following: main instrument structure, detectors, optics, opto-mechanical system, cryogenic system, electrical harness, cables, and electronics.
D2	**Principal Investigator (PI) Rack** Complete Principal Investigator Rack assembly, or assemblies, if more than one PI Rack is used in the instrument design. Includes, but is not limited to, the following: electronics, equipment, and cables within the rack (the PI rack structure itself is Government Furnished Equipment [GFE]).
D3	**Counterweight Rack (CWR)** Complete SI Counterweight Rack assembly, if a Counterweight Rack is used in the instrument design. Includes, but is not limited to, the following: electronics, equipment, and cables to be mounted in one counterweight rack (the counterweight rack structure itself is GFE).
D4	**Interface Cables and Flex Lines**

#	Deliverable Requirement
	a. All SI-to-SI and SI-to-SOFIA cable harnesses, and (where applicable) compressed He and/or vacuum flex lines for operation of the instrument in flight. Includes, but is not limited to, the following: interconnect cables between the counterweight rack and the instrument assembly, and the rack and the instrument to the aircraft patch panels. b. All SI cable harnesses, and (where applicable) compressed He and/or vacuum flex lines for operation or maintenance of the instrument in the ground facility / lab.
D5	**Calibration and Test Equipment** All science instrument specific test equipment needed to calibrate and maintain the instrument.
D6	**Instrument Installation Cart(s)** Cart(s) used for transporting the Science Instrument Assembly through the ground facility and aircraft, and installing the instrument to the Telescope Assembly.
D7	**Ground Support Equipment** a. All ground support equipment (including test cables, special tools and fixtures) used in the lab or ground facility (or SOFIA, for non-flight ground use only) for purposes such as maintenance, assembly / disassembly, operations or optical alignment of the instrument (e.g. turnover carts, test stands). b. Other GSE such as lifting hardware or cryo-fill hardware, especially if unique to the SI design. c. (Where applicable) GSE cryocooler He compressor(s) needed to support operation of the Science Instrument cold head(s) at AFRC B703 in the lab or Preflight Integration Facility (PIF). • Note: GSE cryocooler He compressor(s) delivered for use at AFRC B703 shall comply with the following accommodation constraints: ▪ Compressors to be air-cooled (vs. liquid-cooled), with no more than 8.5 kW max / 7.5 kW steady-state (each) heat rejection to the ambient environment. ▪ Compressors to operate on 120/208 VAC, 3-phase, 60 Hz power, 25 A max (each) ▪ Compressor power cords to be equipped with a Meltric DSN60 (3P + N + G) plug P/N 63-68167, a handle w/ cable range collet clamp P/N 513P0D30, and a finger drawplate P/N 61-6A346. ▪ Compressors to be delivered with CoC documenting compliance with applicable industrial and/or consumer safety codes (e.g., UL 471, Commercial Refrigerators and Freezers) that establishes PVS qualification (burst) and acceptance (proof) pressure testing and certification. d. (Where applicable) GSE cryostat, cold head, He manifold, and associated ancillary equipment needed to support servicing of the Cryocooler He loops in the AFRC B703 facilities and aboard SOFIA (e.g., purging, pumping, refilling and cryotrapping operations).
D8	**Flight Hardware Spares** All spare components to complete the Legacy Science Program exploitation period, based on proposed approach. This includes long lead items and unique parts that might become hard to replace later in the Legacy Science Program exploitation period.

#	Deliverable Requirement
	SOFTWARE
D9	**Instrument Software** This is the actual instrument control and data handling software on CD/DVD, including executables, source code, APIs, libraries, build files, other files required to build the executables, and check cases and/or scripts to support regression testing. Software can be developed using any common language such as Java, C++, or other language if approved by the SOFIA Program.
D10	**Data Reduction Algorithms and Test Data** Data reduction pipeline algorithms and test data to support development and testing of a software data reduction pipeline by the SOFIA Program.
D11	**Software and Test Scripts** Software and test scripts required to calibrate or maintain the instrument.
	DOCUMENTATION
D12	**Project Plan** Fulfilled by the proposal team production of an Instrument Concept Study (ICS) Report (Step-2), per requirements listed in section 6 of the March 6, 2018 amendment of the D.14 SOFIA Next Generation Instrumentation solicitation for proposals.
D13	**Schedule** Instrument development schedule containing sufficient detail for monthly progress tracking provided monthly in native format. (i.e. scheduling software; for example MS Project [.mpp] files are used by the SOFIA Program). Critical and progress milestones will be reviewed and negotiated with the SOFIA Program within 30 days of selection.
D14	**Monthly Status Reports** Description of instrument team's progress over the previous month, including technical status and accomplishments, risks, schedules status, budget status, and photographs and figures of significant accomplishments.
D15	**Yearly Funding Requirement Estimates and Monthly estimates of expenditures** a. Used as inputs to the NASA PPBE process for estimating budgets; includes estimate of funding required for the life cycle of the SI development. Estimates must be provided by government fiscal year and include element of cost detail (labor, travel, procurement, etc.). Elements of cost and reporting details to be negotiated. Budgeting estimates based on cash flow needs or new obligational authority. b. Time-phased budget requirements, (cash flow or new obligational authority) and time-phased cost and invoicing estimates by month, for the life of the project. Detail by month for next 12 months, and by quarter for periods more than 12 months out. c. To enable sufficient insight into budgetary risks (over-runs, under-runs, changes in phasing of funding requirements), actual expenditures (obligation and cost, or details to be negotiated upon award) and

#	Deliverable Requirement
	explanations of variance from the plan for reporting month and cumulative to date. Updated monthly in the Monthly Status Reports. d. Specific reporting formats to be negotiated within 30 days of contract award.
D16	**Science and Performance Requirements** Scientific and technical performance requirements for the instrument. May also list goals if desired. Include rationale for each requirement, and how the requirement relates to the science investigation. Initial draft fulfilled by the proposal team production of an Instrument Concept Study (ICS) Report (Step-2), per requirements listed in section 6 of the March 6, 2018 amendment of the D.14 SOFIA Next Generation Instrumentation solicitation for proposals.
D17	**Science and Performance Requirements Compliance Matrix** Compliance matrix showing verification and compliance of the instrument design with the science and performance requirements defined in the ICS Report. Includes, but is not limited to, the requirement text and requirement ID, verification method(s) employed, phase(s) of instrument development/lifecycle, in which verification is conducted, compliance status, and verification artifacts for each requirement.
D18	**Technical Requirements Compliance Matrix** Compliance matrix showing verification and compliance of the instrument design with the SOFIA SI airworthiness requirements established in the SOF-AR-SPE-SE01-2028, *SOFIA Science Instrument System Specification*, and SOFIA interface control documents, in the format established in SOF-NASA-REP-SV05-2057, *SOFIA Science Instrument System Specification and ICD Requirements Verification Matrix Template*.
D19	**Flight Hardware Drawings** a. All 2D drawings shall be completed using ISO 16792 (ASME Y14.100) drawing standards. b. All drawings must be signed by the originator. c. The SI developer shall supply as-built 3D CAD models in the native CAD file format and one or more generic CAD file formats (e.g. ACIS [SAT], Parasolid, IGES, STEP). d. The SI developer shall supply assembly 2D drawings with associated Bills of Materials (BOMs). e. Master drawing showing hierarchy of all drawings; scope of drawings to include those which are needed for airworthiness certification of instrument design. f. Master list of drawings for airworthiness certification of instrument design including drawing number, title, revision, and next-level assembly. g. Drawings for all hardware included in (emergency landing) ultimate loads structural analyses and calculations, including custom-made and commercial-off-the-shelf (COTS) hardware. Design details for COTS equipment may be supplied through manufacturer drawings or product datasheets. h. Drawings for hardware included in internal, mechanically-induced loads structural analyses and calculations. Assembly drawings for SI flight hardware, needed for purposes such as testing, maintenance, assembly / disassembly, or optical alignment of the instrument. i. Drawing of PI Rack configuration, for each PI Rack used.

#	Deliverable Requirement
	j. Drawing of Counterweight Rack configuration. k. Drawing identifying critical fasteners (instrument internal and external) and non-critical external fasteners; these fasteners are required to have self-retaining or self-locking features. l. Drawing of instrument mounting flange that will mate with SOFIA Telescope Assembly (TA) Instrument Mounting Flange (IMF). m. Drawing of instrument hardware which mounts to the Gate Valve Pressure Plate (GVPP) hardpoints inside the TA Instrument Flange (INF) tub. n. Drawing of pressure coupler or optical window hardware which will mount directly to the TA GVPP interface flange. o. Drawings of cryogen reservoir, vent system, pressure relief valves (PRVs), rupture pin/burst disk, "drop-off plate" relief port and plate, and other components of the cryogen reservoir and vent / cryogen fill system, including identification of material. p. Drawing of SI cryocooler configuration (system level drawing of pressure system). q. Component drawings for SI cryocooler cold head, rotary valve, and other pressure components and lines that are part of the SI cryocooler system. r. Drawing of external flexible hose configuration (e.g., helium gas, vacuum lines) and location of strain relief, standoffs, and tie-down provisions. s. Drawing of overall instrument system cable harness / wiring scheme. t. Drawing of power distribution scheme including circuit interruption devices. u. Drawing of protection of high-voltage terminals. v. Drawing of instrument electrical safety ground scheme, internal to instrument, and grounding scheme to SOFIA. w. Drawing of SI Uninterruptible Power Supplies (UPS) and signal distribution of SOFIA Emergency Power Disconnect (EPD) at a system level. x. Drawings of electrical safety ground cables or straps. y. Other general content requirements: • Provide weld details in drawings (e.g., welding standard applied, welding process (e.g., GTAW), weld classification (e.g., Class A, B, C), other necessary welding properties and dimensional information).
D20	**Critical Safety Items List** A detailed list, including part numbers and drawing numbers, of the parts of the instrument that are classified as "safety critical"; safety critical is defined in the NASA SOFIA Science Instrument Development Decision Memorandum as: "***Safety Critical**—a failure to meet the flight hardware or software requirements for that characteristic could cause or lead to severe injury, major damage, or mission failure if performed or built improperly, or allowed to remain uncorrected. The loss of the SI by itself does not constitute a mission failure." The following items are expected to be included in this list if the instrument design contains these design features: 1) Instrument assembly structure mounted to the telescope, consisting of instrument mounting

#	Deliverable Requirement
	flange, outer structure, fasteners, and externally mounted components of the instrument assembly; 2) Equipment inside the PI Rack and Counterweight Rack, with emphasis on equipment mounting to rack, equipment structure, and containment of internal components; 3) All components and parts that contact liquid helium; 4) All pressure relief devices and burst disks associated with venting of cryogen reservoirs; 5) Overcurrent protection devices in PI Rack, Counterweight Rack, and instrument assembly; 6) Electrical safety ground jumper cables or straps.
D21	**Quality Plan** The Quality Plan includes a description of the following a. SI developer QA organization and structure, and responsibilities of the SI developer QA Lead. b. Process evaluation & control (quality support during requirement definition, quality support during design). c. Procedure evaluation. d. Product examination (e.g., witness activities), inspection, test, and non-destructive evaluation (NDE), functional configuration audits (FCA), and physical configuration audits (PCA) e. Metrology and calibration. f. Non-conformances and discrepancies. g. Shipping and receiving. h. Record control (configuration management, documentation and record control). i. Procurement quality assurance.
D22	**Master Parts List (MPL)** Complete list of hardware components including part identification/numbers, quantity, weight, operating temperature, survival temperature, and if applicable, power consumption for instrument assembly, rack equipment, and other SI flight hardware (e.g., pressure coupler). For electronic components, manufacturer and lot date code must also be included, if applicable. Within the MPL, identify the minimum list of equipment needed to support SI operation onboard the SOFIA aircraft.
D23	**Electrical Systems Report** a. List of drawings for the instrument electrical / electronic system (i.e., the required drawings specified in the Drawing Deliverables Section) and rack configuration drawings. b. Description of the overall instrument electrical system. c. Functional description of electronics. d. List of circuit interruption devices used in instrument design, including model/part number, trip ratings, and datasheets for COTS components. e. List of SI Uninterruptible Power Supplies (UPS) and datasheets for any COTS UPS. f. Description of any modifications made to COTS equipment. g. Description of cable identifier naming scheme (nomenclature) if any unique scheme is used. h. List of cables including: unique cable identifier; cable function description; identification of wire, jacketing, and connector part numbers and manufacturer; cable connection locations; wire conductor size, current and temperature rating, and insulation material; jacket material if used; and datasheets for COTS components.

#	Deliverable Requirement
	i. A report covering the science instrument electrical power draw during each operations phase, including power-up with any inductive or capacitive inrush loads identified.
D24	**Instrument Structural Analysis** a. Margin of Safety table summarizing the results of all analyses performed. b. Identification of cryostat assembly mass and C.G. in the instrument coordinate system, and telescope U,V,W coordinate system; provide reference to MPL for lower-level mass information. c. Analysis of instrument hardware for emergency landing / crash load conditions, using the specified Ultimate Load factors. d. Analysis of instrument hardware for internal, mechanically-induced loads using the specified Factors of Safety. e. Analysis of maximum volume of liquid cryogens contained within the instrument. f. Analysis of cryogen reservoir and primary and backup (emergency) vent / fill neck tubes for rapid cryogen boil-off, cryogen reservoir Loss of Vacuum (LOV) event, using the specified qualification pressure levels (i.e., Maximum Normal Operating Pressure (MNOP) (or Pmax for LHe reservoirs) multiplied by a Safety Factor). Analysis must consider material properties at cryogenic temperatures, where appropriate. g. Analysis of instrument hardware due to pressure loads from the aircraft pressure boundary differential. h. Analysis for loading of instrument hardware on TA GVPP pressure coupler/optical window interface (where applicable). i. Analysis for loading of instrument hardware on TA GVPP hardpoints (where applicable). j. Analysis of SI cryocooler system components, using specified qualification pressure levels (i.e., MNOP multiplied by a Factor of Safety). k. Analysis of maximum pressure within SI cryocooler system caused by warming of system components, and trapped helium gas, to aircraft cabin temperature during periods of non-operation of the cryocooler system on SOFIA. l. Other general content requirements: • Calculations show assumptions, allowable stresses, load path definition, free-body diagrams, rationale, results, and analysis. Calculations must be reviewable showing how the results were produced, and include enough information to allow an independent reviewer to understand and identify any errors. ▪ Structural analysis report must contain analysis of regions with the highest stress concentration or where damage or structural failure is most likely to occur. ▪ Structural analysis must include all likely stresses, and also some of the most commonly overlooked calculations such as bending failure, pure bolt tension or shear, and shear tear-out values. ▪ Statements explaining if the component masses were determined by measurement (test) or calculation (analysis).

#	Deliverable Requirement
	• Finite Element Models, if any, identify software used, methods, and parameters (mesh, element type, size, constraints, convergence analysis, etc.). FEM results must be reviewable. • Include safety critical welds and critical fasteners in structural analyses.
D25	**Rack Mass Analysis** a. List of PI Rack and Counterweight Rack assembly drawings. b. Calculations for each PI Rack: SI payload weight in each front and back section of each bay (4 sections total), payload weight in each bay (2 bays total), total payload weight in PI rack, and total overturning moment of payload in PI Rack. c. Calculations for Counterweight Rack: mass and effective c.g. of SI payload configuration.
D26	**System Safety Assessment (SSA)** a. A description, including design characteristics and/or functional operations, of the system or subsystem being analyzed, and its relation to the overall instrument. b. Identification and analysis of hazards through analysis for the system/subsystem (e.g. cooling system hazards associated with cryogens, cryocoolers, sorption fridges, etc.), loss of cryostat vacuum, cryostat overpressure, electrical system hazards, software hazards, electrical load analysis, electrical grounding, and magnetic fields (e.g. ADR) hazards. Identify the mitigations against the hazards. Provide quantified description of the risk whenever possible. c. Analysis of the following additional operational scenarios: 1) Loss of input power to the instrument; 2) Loss of command and control of the instrument; 3) Internal software failure; 4) SI System internal power supply failure or failure of other SI electrical or electronic components. d. Identification and description of any critical wiring needed to maintain control of the instrument for safety, and the wire routing design.
D27	**Test Plan(s)** Test plan(s) for qualification and acceptance testing of pressurized systems and components (e.g., cryogen reservoir and fill / vent neck tube system, cryocooler components). For hardware in which the Proto-Flight (PF) Qualification approach is employed, only qualification testing is required. COTS components accompanied by proper certification documentation may fulfill qualification and/or acceptance pressure test criteria.
D28	**Test/Inspection Reports** a. Inspection reports for custom manufactured parts that are safety critical. b. Inspection reports for welds on parts that are safety critical. c. Test report providing results of pressure test for cryogen reservoir and fill/vent neck, including inspection results. d. Test reports for SI cryocooler hardware qualification and acceptance pressure tests. e. Test report of measured magnetic field outside of the instrument, for instruments that generate high internal fields such as by use of adiabatic demagnetization technology.

#	Deliverable Requirement
D29	**Certification Documentation** a. Hardware certification documentation for safety critical hardware as applicable: manufacturer certificates of conformance (CoC), physical/chemical test reports, raw material certificates, and process certificates. b. Personnel certification documentation for welding, Nondestructive Testing (NDT) / Nondestructive Evaluation (NDE), and inspection of safety critical hardware.
D30	**Software requirements document** Software requirements for the science instrument. Verification method and phasing must be included. Also, provide a brief description of planned verification activities to be performed including citation of verification procedures to be executed wherever appropriate, verification status, test case/verification compliance artifact, verification remarks/rationale.
D31	**Software test reports** Software test reports that detail results of witnessed testing.
D32	**Software Version Description Document (VDD)** Published with each software release delivered for integrated test activities; Describes software delivered on media, including checksums (such as SHA1 or MD5) or other means to audit each release. Describes specific changes in each release as well as known problems.
D33	**Software Verification and Validation (V&V) test plan and procedures** Test plan and procedures used to test all software. Tier tests, which test interactions with the Observatory, are written by SOFIA Software Systems and Mission Operations.
D34	**Instrument to Data Cycle System (DCS) interface control document** Describes, at a minimum, specific values for DCS integration for proposal tool, keyword meanings, pipeline execution parameters, etc.
D35	**Instrument Operations Concept** Overview description of how the instrument will operate and interact with the other Observatory subsystems. Baseline fulfilled by proposal team production of an Instrument Concept Study (ICS) Report (Step-2), per requirements listed in section 6 of the March 6, 2018 amendment of the D.14 SOFIA Next Generation Instrumentation solicitation for proposals.
D36	**Instrument Assembly Mass and CG ICD Analysis Report** Compliance analysis of the instrument with the mass and center of gravity limits defined in SOF-DA-ICD -SE03-037 (TA_SI_02) and SOF-AR-ICD-SE03-2027 (SI_CWR_01). This analysis pertains to the instrument assembly, Counterweight Rack, and any other SI components mounted to the telescope assembly.
D37	**ICD Dynamic Envelope Analysis** a. Drawing or diagram of instrument in its TA installation/flight configuration superimposed (integrated) with the SOFIA ICD SI Dynamic Envelope, with sufficient views to show compliance of the SI with

#	Deliverable Requirement
	all aspects of the ICD envelope, and dimensional clearance information for features of the instrument closest to the ICD envelope boundary. b. Compliance analysis of the instrument with the allowable SI dynamic, static, and installation envelopes defined in SOF-DA-ICD-SE03-002 (GLOBAL_09).
D38	**Ground Support Equipment Drawings** All 2D drawings shall be completed using ISO 16792 or ASME Y14.100 drawing standards. Part and assembly drawings for SI GSE such as installation cart, lab stand/turnover carts, custom lifting hardware, needed for purposes such as testing, maintenance, assembly/disassembly, or optical alignment of the instrument. Provide weld details in drawings (e.g. welding standard applied, welding process (e.g. GTAW), weld classification (e.g. Class A, B, C), and other necessary welding properties and dimensional information).
D39	**Instrument cart/stand ICD analysis report(s)** Compliance analysis of instrument cart/stand ground support equipment with the interface requirements defined in SOF-AR-ICD-SE03-205 (SIC_AS_01) and SCI-AR-ICD-SE03-2017 (SIC_SSMO_01).
D40	**Instrument cart/stand structural analysis report(s)** Compliance analysis of instrument cart/stand ground support equipment, with the applicable structures safety requirements of SOF-AR-SPE-SE01-2028 (paragraph ID 3.5.2 and subparagraphs). Include safety critical welds and critical fasteners in structural analyses.
D41	**Ground support equipment load test procedure** Procedure for conducting load tests for SI stands and carts to comply with SOF-AR-SPE-SE01-2028, paragraph 3.5.2.3.
D42	**Instrument configuration sheet** a. The SI developer will develop an Instrument Configuration Sheet appropriate for their instrument, describing the instrument hardware and software configuration. This sheet will be a brief form that will list the software versions loaded on the instrument flight computers as well as information on the instrument that may vary from flight to flight, such as the channels installed, the filter wheel complements, the detector serial number, the window serial number, etc. This form establishes, for each installation, a record of the instrument configuration on the aircraft. The instrument configuration sheet will be included in Observatory Configuration Change Requests for the aircraft, serving as documentation for the instrument configuration for a particular installation. The SMO may use these instrument configuration records for instrument anomaly investigation and science data processing. b. The Instrument Configuration Sheet will be updated by the SI developer (or Instrument Scientist for accepted instruments), and submitted to the SOFIA Program prior to each pre-installation review. c. The SI developer must also provide a Version Description Document (VDD) for each software integration test that records the versions of the software being tested.
D43	**Instrument maintenance logbook** Log of instrument changes following instrument ICD verification and airworthiness approval.

#	Deliverable Requirement
D44	**Commissioning plan** Plan for the commissioning of instrument including a description of laboratory, on-aircraft, and airborne tests that need to be performed to commission all the observing modes of the instrument. The commissioning plan also contains the following: a. Inputs to SOFIA Line Operations Plan: Inputs to plan for testing the instrument on the aircraft while on the ground, covering both tests that can be accomplished in the hangar, as well as tests done on the flight line (observing the sky). b. Calibration Plan: Description of instrument calibration approach, including acquisition and application of flat fields, corrections for detector non-linearity, how data needed for these calibrations will be obtained, and how/where in the pipeline reductions they will be applied. Wavelength calibration must be described for spectrograph instruments. The SI developer must describe how calibration will be performed for telluric corrections and flux calibration. c. Legacy Science Program (LSP) Observing Plan: Plan for science investigations to be executed during the LSP exploitation period, per the Legacy Science Program defined within the ICS Report.
D45	**Commissioning report** The commissioning report describes the instrument status and performance, operational modes, expected sensitivities in all modes, and best practices for the use of the instrument for science.
D46	**Operations manual** A "Users Guide" for the general community, and manual describing how to operate the instrument hardware and software on SOFIA. It must include a section on how to address off-nominal conditions such as an ice plug, or how the operators should react to a release valve operating. It shall include the following operations procedures and procedure inputs: a. Instrument warm functional check: Procedure for checking the instrument's health status while warm (ambient) that will be performed prior to cooldown. b. Instrument cool down procedure: This is a cryogen fill procedure, or a cryocooler operating procedure to bring the instrument to operating temperature. c. Maintaining instrument operating temperature procedure: This is a cryogen fill procedure, or a cryocooler operating procedure to maintain the instrument at operating temperature. d. Instrument cold functional check procedure: Procedure for checking the instrument's health status while cold, prior to line operations testing or flight. e. Inputs to SOFIA SI installation procedure: Detailed procedure steps provided by the SI developer for installing the instrument assembly onto the telescope flange, any integration of components, which has to be performed inside the aircraft after being brought onboard the aircraft, and cable connections. (Inputs for mounting and installation of PI rack or counterweight rack structures are not necessary from the SI developer; generic SOFIA procedures exist that cover rack installation for all instruments.). f. Inputs to SOFIA SI removal procedure: Detailed procedure steps provided by the SI developer for removing the instrument assembly from the telescope flange, any de-integration of components, which has to be performed inside the aircraft prior to removal from the aircraft, and cable disconnections. (Inputs for the unmounting and removal of PI rack or counterweight rack structures are not necessary from the SI developer; generic SOFIA procedures exist that cover rack removal procedures for all instruments.).

#	Deliverable Requirement
D47	**Maintenance manual** Manual describing how to perform maintenance of the instrument hardware and software, such as how to open and close the instrument, perform optical alignment, and perform expected and probable hardware and software maintenance on the instrument. The maintenance manual also contains the following: a. Spare hardware list: A list of spare or loose hardware needed to complete the Legacy Science Program based on proposed approach.
D48	**Shipping Plan** a. Description of how the instrument will be packed and shipped to AFRC Building 703. b. Description of instrument configuration and components for shipping in the SOFIA cargo bay. c. Description of any instrument cryogen or power needs during shipping in the SOFIA cargo bay. d. List of any additional structural analyses performed that are unique to the configuration of the instrument assembly or components, when shipped in the SOFIA cargo bay.
D49	**Initial Formulation Review chart package** Refer to the SCI-AR-HBK-OP03-2000; Science Instrument Developers' Handbook for chart package content.
D50	**Final Formulation Review chart package** Refer to the SCI-AR-HBK-OP03-2000; Science Instrument Developers' Handbook for chart package content.
D51	**Pre- Install Review chart package** Refer to the SCI-AR-HBK-OP03-2000; Science Instrument Developers' Handbook for chart package content.
D52	**Operations Acceptance Review chart package** Refer to the SCI-AR-HBK-OP03-2000; Science Instrument Developers' Handbook for chart package content.
D53	**Inputs to SOFIA SI Electromagnetic Interference (EMI) Test Plan** Frequency inputs for electromagnetic compatibility (EMC) demonstration that will be performed with the instrument onboard SOFIA, with the aircraft on the ground with engines running and instrument and aircraft systems operating; considerations include conducted/radiated emissions and conducted/radiated susceptibility. Consult with Program for extent of information needed from instrument developer.
D54	**SOFIA SI Hazard Reports** Hazard Reports (HRs) for a science instrument identify hazards inherent with the design and operation of the science instrument. Each HR listed and verifies mitigations of the hazards to minimize its risk. They include an assessment of the likelihood and criticality of the hazard both before and after mitigations are provided. Reliability analysis may be required based on applicable safety requirements and/or to assist in likelihood assessment of the hazard. While the SI Developer provides draft HRs and assists in their disposition, the SOFIA System Safety Working Group (SSWG) is the final disposition authority.

#	Deliverable Requirement
D55	**General Design Reference Items** This deliverable is a catch all of SI design articles, for the program to be able to reference if needed, after the SI is transferred to NASA. Items in this deliverable are not subject to any formal review. a. As-built 3D CAD models in the native CAD file format. b. 2D drawings. c. Bills of Materials (BOMs). d. The SI as-built optical design files (Zemax, Code V, OptiCAD or similar). e. The SI structural or thermal modelling files (Thermal Desktop, ANSYS or similar FE/FD analysis codes). f. Any other available files representative of the SI design or analysis that can be used for SI operation, maintenance or modification.

Appendix A - Deliverable Schedule

The table in Appendix A presents the document deliverable items, organized by the respective instrument Key Decision Points (KDPs). Successfully completing an instrument technical review will depend on a number of key factors, one of which is timely delivery of documentation by the instrument developer to the SOFIA Program prior to Key Decision Points (KDPs).

Acronym	Definition
KDP	Key Decision Point
AW	Airworthiness
GS	Ground Safety
MA	Mission Assurance
PM	Project Management

Symbol	Definition
○	Initial or updated draft release
●	Baseline release; typically, a final release
▲	Typical updated release following a baseline release (if necessary)
I	Inputs from SI developer

Item #	Deliverable	Type	KDP A (PR)	KDP B (IFR)	KDP C (FFR)	KDP D (PSE)	KDP E (PIR)	KDP F (OAR)	Template Available
	HARDWARE								
D1	Science instrument assembly	AW				●	▲	▲	N/A
D2	PI Rack	AW				●	▲	▲	N/A
D3	CW Rack	AW				●	▲	▲	N/A
D4	Interface Cables	AW				●	▲	▲	N/A
D5	Calibration and Test equipment	MA				●			N/A
D6	Instrument Installation Cart(s)	GS				●			N/A
D7	Ground Support Equipment	GS				●			N/A
D8	Flight Hardware Spares	MA						●	N/A
	SOFTWARE								
D9	Instrument Software	MA				○	○	●	N/A
D10	Data reduction algorithms and test data	MA				○	○	●	N/A
D11	Software and test scripts	MA				○	○	●	N/A
	DOCUMENTATION								
D12	Project Plan	PM	●						*None
D13	Schedule	PM	Update monthly under contract						Negotiate
D14	Monthly status reports	PM	Update monthly under contract						Synopsis
D15	Yearly funding requirements estimates and monthly estimates of expenditures	PM	Update annually and monthly						Negotiate
D16	Science and performance requirements	MA	○	●	▲				Synopsis
D17	Science and performance requirements compliance matrix	MA		○	○	○	○	●	Synopsis
D18	Technical requirements compliance matrix	AW		○	○	○	○	●	Template
D19	Flight hardware drawings	AW		○	●	▲			*None
D20	Critical safety items list	AW		○	○	●			Template
D21	Quality plan	AW		○	●				Synopsis
D22	Master Parts List (MPL)	AW		○	○	●			Template
D23	Electrical systems report	AW		○	●	▲			Synopsis
D24	Instrument structural analysis	AW		○	●	▲			Synopsis
D25	Rack Mass Analysis	AW		○	●	▲			Synopsis
D26	System Safety Assessment	AW		○	●	▲			Synopsis
D27	Test plan(s)	AW			●				Synopsis
D28	Test/Inspection reports	AW				●			Synopsis
D29	Certification Documentation	AW				●			*None
D30	Software requirements document	MA		●	▲				Synopsis

Item #	Deliverable	Type	KDP A (PR)	KDP B (IFR)	KDP C (FFR)	KDP D (PSE)	KDP E (PIR)	KDP F (OAR)	Template Available
D31	Software test reports	MA				○	●		*None
D32	Software version description document	MA			○	○	○	●	*None
D33	Software Verification and Validation (V&V) test plan and procedures	MA			○	●			*None
D34	Instrument to DCS interface control document	MA		○	○	●			Synopsis
D35	Instrument operations concept	MA	●	▲					Synopsis
D36	Instrument assembly mass and c.g. ICD analysis report	AW		○	●	▲			*None
D37	ICD dynamic envelope analysis	AW		○	●	▲			Synopsis
D38	Ground support equipment drawings	GS		○	●	▲			*None
D39	Instrument cart/stand ICD analysis report(s)	GS			●	▲			*None
D40	Instrument cart/stand structural analysis report(s)	GS			●	▲			*None
D41	Ground support equipment load test procedure	GS				●			*None
D42	Instrument configuration sheet	MA					●		Synopsis
D43	Instrument maintenance logbook	MA						●	*None
D44	Commissioning plan	MA			○	○	●		Synopsis
D45	Commissioning report	MA						●	Synopsis
D46	Operations manual	MA			○	○	○	●	*None
D47	Maintenance manual	MA			○	○		●	*None
D48	Shipping plan	AW				●			Synopsis
D49	Initial Formulation Review chart package	PM		●					Handbook
D50	Final Formulation Review chart package	PM			●				Handbook
D51	Pre- Install Review chart package	AW					●		Handbook
D52	Operations Acceptance Review chart package	MA						●	Handbook
D53	Inputs to SOFIA SI Electromagnetic Interference (EMI) Test Plan	AW				I			*None
D54	SOFIA SI Hazard Reports	AW/ GS		○	○	●	▲		Template
D55	General Design Reference Items	MA	After Commissioning						*None

*None – These Synopsis or Templates were not available at the time this document was baselined. Check with the SOFIA SI Development Manager for availability.

Appendix B – Key Decision Points (KDPs) and Reviews

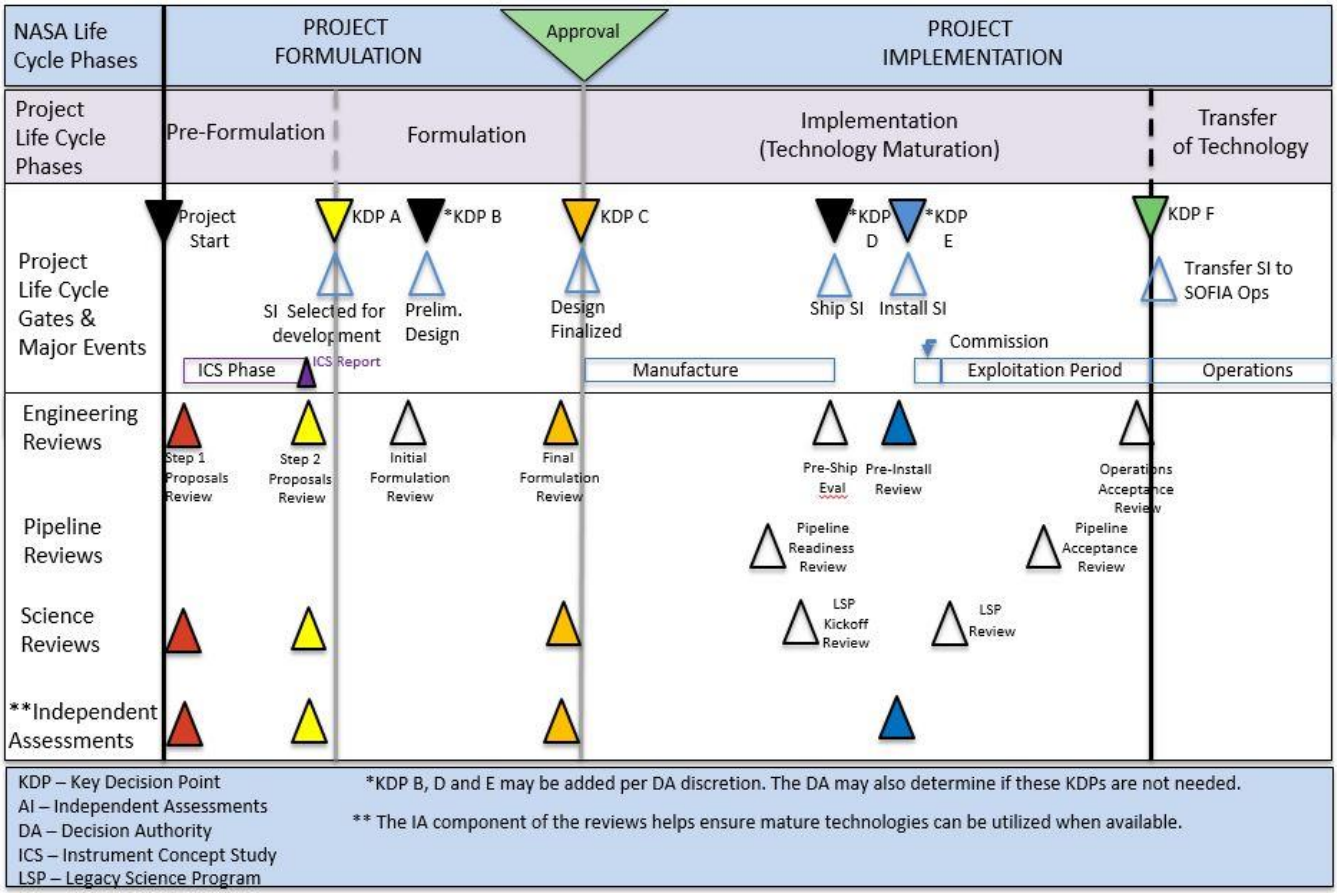

Figure B-1: SI Development Project Life Cycle

1. KEY DECISION POINTS

KDP A

Decision Authority: Director, Astrophysics Division in Science Mission Directorate (SMD)

- Contractual documents issued.
- Proposal(s) for further development identified.

KDP B

Decision Authority: SOFIA SI Development Project Manager

- Decision to continue or discontinue development of SI.

KDP C

Decision Authority: SOFIA SI Development Project Manager

- Decision to continue to or discontinue manufacture of SI.

KDP D

Decision Authority: SOFIA SI Development Project Manager

- Decision to ship SI to Armstrong Flight Research Center or not.

Decision Authority: SOFIA Operations Lead / SIAT Chair

- Decision to as to whether SI Airworthiness is at appropriate level for this KDP.

KDP E

Decision Authority: SOFIA Operations Director

- Decision to proceed to install SI onboard the SOFIA aircraft or not.

KDP F

Decision Authority: SOFIA SI Development Project Manager with concurrence from SMO Director

- Decision to accept and transfer SI to NASA ownership or not.

2. SUMMARY OF REVIEWS

Step 1 Proposals Review (PR)

- Decision Authority: Director, Astrophysics Division in Science Mission Directorate (SMD)
- External Independent Assessment: Yes
- The SI team will produce a proposal (Step-1), per requirements listed in section 5 of the March 6, 2018 amendment of the D.14 SOFIA Next Generation Instrumentation solicitation for proposals.
- Proposal to be developed further will be identified.

Step 2 Proposals Review (PR)- this review replaces the System Requirements Review (SRR) from the solicitation.

- Decision Authority: Director, Astrophysics Division in SMD
- External Independent Assessment: Yes
- The SI team will produce an Instrument Concept Study (ICS) Report (Step-2), per requirements listed in section 6 of the March 6, 2018 amendment of the D.14 SOFIA Next Generation Instrumentation solicitation for proposals.
- Proposal to be developed further will be identified.

Initial Formulation Review (IFR) – this review replaces the Preliminary Design Review (PDR) from the solicitation.

- Decision Authority: SOFIA SI Development Project Manager
- External Independent Assessment: No
- SI team describes the complete system design and justifies that it has completed a credible and acceptable instrument development formulation, is prepared to proceed with the detailed design, and is on track to complete the instrument development in order to meet the instrument performance requirements within the identified cost and schedule constraints.
- Recommendations to continue or discontinue development will be acquired.

Final Formulation Review (FFR) - this review replaces the Critical Design Review (CDR) from the solicitation.

- Decision Authority: SOFIA SI Development Project Manager
- External Independent Assessment: Yes
- The SI team describes the complete system design to the review team and justifies that the maturity of the design and development effort is appropriate to support proceeding with full scale fabrication activities to meet the science investigation performance requirements within the identified cost and schedule constraints.
- Recommendations to continue to or discontinue manufacture will be acquired.

Pipeline Readiness Review (PRR) (occurs ~ 6 months prior to PIR)

- Decision Authority: SOFIA SI Development Project Manager

- External Independent Assessment: No
- This review is to ensure the science data pipeline has been completed and is ready to for processing data that will be collected during the exploitation period.
- Recommendations to proceed with pipeline development will be acquired.

LSP Kickoff Review (occurs ~ 6 months prior to commissioning)

- Decision Authority: SOFIA Science and Mission Operations (SMO) Director
- External Independent Assessment: No
- SI team will provide a LSP observing plan, to be evaluated and allow SOFIA sufficient time to schedule observations.

Pre-Shipment Evaluation (PSE)

- Decision Authority: SOFIA SI Development Project Manager
- External Independent Assessment: No, however, AFRC Lifting Device Equipment Manager (LDEM) and AFRC Bldg. 703 Maintenance and Engineering representatives are critical to this review and participation is requested in this evaluation.
- Instrument team will provide documentation for evaluation of sub-system and integrated instrument performance, interfaces, a successful completion of airworthiness approval by the SIAT, and descriptions of instrument operations.
- Instrument team will provide logistics plan details for shipment to AFRC Bldg. 703
- Recommendations to ship or not ship SI to AFRC will be acquired.

Pre-Install Review (PIR)

- Decision Authority: SOFIA Operations Director
- External Independent Assessment: Yes
- This review is to ensure that all the subsystems are ready for instrument installation and that the roles and responsibilities of team members participating in the installation are understood.
- The SI team must successfully unpack and reassemble the instrument and complete successful ground checks prior to this review.
- For the first installation of an instrument onto SOFIA, the verification status of all requirements will be presented. With the exception of requirements that will be verified after installation or during commissioning, all applicable requirements must be declared pass (complies) or have approved deviations or waivers.
- Recommendations to proceed to install SI onboard the SOFIA aircraft will be acquired.

LSP Review (post commissioning)

- Decision Authority: SOFIA Science and Mission Operations (SMO) Director
- External Independent Assessment: No
- After the instrument performance is verified, the SI team will support an LSP review at which point the SMO director will formally authorize observation, in concurrence with NASA.

Pipeline Acceptance Review (PAR) (occurs ~ 6 months prior to AR)

- Decision Authority: SOFIA SI Development Project Manager
- External Independent Assessment: No
- This review is to ensure the science data pipeline has been completed, any final modifications have been made, and it is ready for processing data that will be collected by observers during operations.
- Recommendations to accept the science data pipeline will be acquired.

Operations Acceptance Review (OAR)

- Decision Authority: SOFIA Observatory Systems Director and the SOFIA Project Scientist
- External Independent Assessment: No
- Demonstrate readiness of the SI to be operated and maintained by SOFIA staff.
- Demonstrate that the associated deliverables are complete and reflect the delivered system.
- Demonstrate that science performance is acceptable.
- Recommendations to accept and transfer SI to NASA ownership or not will be acquired.

3. ENTRANCE/ SUCCESS CRITERA FOR REVIEWS

The following describes the instrument development technical reviews and are presented in the order they occur according to the SI development project life-cycle.

Assessment of any subjective terms will be discussed on a bilateral basis, but final assessment and determination is held by the review Decision Authority.

3.1 Step 1 Proposals Review

The SI team will produce a proposal (Step-1), per requirements listed in section 5 of the March 6, 2018 amendment of the D.14 SOFIA Next Generation Instrumentation solicitation for proposals.

3.2 Step 2 Proposals Review

The SI team will produce an Instrument Concept Study (ICS) Report (Step-2), per requirements listed in section 6 of the March 6, 2018 amendment of the D.14 SOFIA Next Generation Instrumentation solicitation for proposals.

3.3 Initial Formulation Review (IFR)

The IFR demonstrates that the preliminary design meets all SI design requirements with acceptable risk and within the cost and schedule constraints. It establishes the basis for proceeding with detailed design.

The IFR is chaired by the SOFIA SI Development Manager. The SOFIA SI Development Manager forms a review panel to assess whether the IFR success criteria have been met. The review panel is composed of SOFIA staff members including the SOFIA SI Development Manager, Project Scientist, Observatory Systems Director, SSMO Director, Operations Director, SOFIA Chief Engineer, SE&I Lead, SIAT Lead, and SOFIA S&MA Lead.

After completing the IFR, minutes of the meeting are to be published and distributed. The minutes are to contain at least the presentations, documentation of any decisions made, attendees, and action items. Closure date and person responsible for addressing the action are to be identified.

Table B-1 – Entrance /Success Criteria for the IFR

Entrance Criteria
1. A preliminary IFR agenda and chart content for the technical review have been agreed to by the instrument developer and SOFIA SI Development Manager.
2. The IFR technical products identified in Section 3 and Appendix A, KDP B have been delivered by the instrument developer to the SOFIA program.
Success Criteria

1. The preliminary design is expected to meet the SI design requirements identified in SOF-AR-SPE-SE01-2028; SOFIA Science Instrument System Specification; and SOFIA SI Interface Control Documents (ICDs) at an acceptable level of risk, and within the planned cost and schedule; and shows sufficient maturity to proceed to final design.
2. The flowdown of verifiable requirements to lower-level specifications (e.g. software requirements documents) is complete.
3. Definition of the technical interfaces between the SI and the SOFIA aircraft is consistent with the overall technical maturity and provides an acceptable level of risk.
4. (If applicable) Any required new technology is developed to an adequate state of readiness, or backup options exist and are supported to make them viable alternatives.
5. Risks are understood and have been credibly assessed.
6. Applicable Safety and mission assurance (e.g., safety, maintainability) requirements have been adequately addressed in preliminary designs and any applicable products (e.g., system safety analysis), at the appropriate maturity level for this period of the SI development project life cycle.
7. Adequate technical and programmatic margins (e.g., mass, power, memory) and resources exist to complete the SI development within budget, schedule, and known risks.
8. The operational concept is technically sound, and the SI concept of operations has been updated to reflect the approved design.
9. Technical trade studies are mostly complete to sufficient detail and remaining trade studies are identified, plans exist for their closure, and potential impacts are understood.
10. TBD and TBR items are clearly identified with acceptable plans and schedule for their disposition.
11. Preliminary modeling and analysis results are available and have been considered in the design.
12. (If applicable) Heritage designs have been assessed for applicability and appropriateness.
13. A conceptual test and evaluation strategy has been formed.
14. Manufacturability has been adequately included in design.
15. Software components are being developed per the SOF-NASA-PLA-PM20-2011; SOFIA Software Management Plan.

3.4 Final Formulation Review (FFR)

The FRR demonstrates that the SI design meets SI development requirements with acceptable risk and within the cost and schedule constraints and establishes the basis for proceeding with implementation of the detailed design and fabrication activities.

The FFR is chaired by the SOFIA SI Development Manager. The SOFIA SI Development Manager forms a review panel to assess whether the FFR success criteria have been met. The review panel is composed of SOFIA staff members including the SOFIA SI Development Manager, Project Scientist, Observatory Systems Director, SSMO Director, Operations Director, SOFIA Chief Engineer, SE&I Lead, SIAT Lead, and SOFIA S&MA Lead.

After completing the FRR, minutes of the meeting are to be published and distributed. The minutes are to contain at least the presentations, documentation of any decisions made, attendees, and action items. Closure date and person responsible for addressing the action are to be identified.

Table B-2 – Entrance /Success Criteria for the FFR

Entrance Criteria
1. The development team has successfully completed the previous planned milestone reviews and RFIs/RFAs/action items have been addressed with the concurrence of the originators, or a timely closure plan exists for those remaining open.
2. A preliminary FFR agenda and chart content for the technical review have been agreed to by the instrument developer and SOFIA SI Development Manager prior to review.
3. The FFR technical products identified in Section 3 Appendix A, KDP C have been delivered by the instrument developer to the SOFIA program.
Success Criteria
1. The detailed design is expected to meet the SI design requirements identified in SOF-AR-SPE-SE01-2028; SOFIA Science Instrument System Specification; and SOFIA SI Interface Control Documents (ICDs) at an acceptable level of risk, and within the planned cost and schedule; and shows sufficient maturity to proceed with implementation.
2. Technical interface designs between the SI and the SOFIA aircraft are appropriately matured to proceed with fabrication, assembly, integration, and test, and plans are in place to manage any open items.
3. (If applicable) Any required new technology is developed to an adequate state of readiness, or backup options exist and are supported to make them viable alternatives.
4. (If applicable) The flowdown of verifiable requirements to lower-level specifications (e.g. software requirements documents) is complete or, if not, an adequate plan exists for timely resolution of open items.
5. Risks are understood and have been credibly assessed.
6. Applicable Safety and mission assurance (e.g., safety, maintainability) requirements have been adequately addressed in detailed designs and any applicable products (e.g., system safety analysis), are at the appropriate maturity level for this period of the SI development project life cycle.

7. Adequate technical and programmatic margins (e.g., mass, power, memory) and resources exist to complete the SI development within budget, schedule, and known risks.
8. The operational concept is technically sound, and (if applicable) the SI concept of operations has been updated to reflect the approved design.
9. The product verification and validation plans are complete.
10. All IFR RFIs, RFAs, TBD and TBR items against the design have been resolved and dispositioned, or, if not, an adequate plan exists for timely resolution of open items.
11. Appropriate modeling and analysis results are available and have been considered in the design.
12. (If applicable) Heritage designs have been suitably assessed for applicability and appropriateness.
13. Manufacturability has been adequately included in design.
14. Software components are being developed and deployed per the SOF-NASA-PLA-PM20-2011; SOFIA Software Management Plan.

3.5 Pipeline Readiness Review (PRR)

The purpose of the PRR is to ensure the science data pipeline has been completed and is ready to for processing data that will be collected during the exploitation period.

The PRR is chaired by the SOFIA SI Development Manager. The SOFIA SI Development Manager forms a review panel to assess whether the PRR success criteria have been met. The review panel is composed of SOFIA staff members including the SOFIA SI Development Manager and SOFIA Pipeline Development Lead.

After completing the PRR, minutes of the meeting are to be published and distributed. The minutes are to contain at least the presentations, documentation of any decisions made, attendees, and action items. Closure date and person responsible for addressing the action are to be identified.

Table B-3 – Entrance /Success Criteria for the PRR

Entrance Criteria
1. A preliminary agenda, instructions to the review team and chart content for the PRR have been agreed to by the instrument developer and SOFIA SI Development Manager.
2. The SOFIA pipeline team has received all the necessary deliverables to allow them to complete development of the data reduction pipeline and calibration.
Success Criteria
1. Data reduction pipeline plan is complete and resources are ready to process data during commissioning and the LSP exploitation period.

3.6 Legacy Science Program (LSP) Kickoff Review

The purpose of the LSP Kickoff Review is to demonstrate that the instrument meets the originally proposed science performance requirements and to evaluate the preliminary LSP observing plan for the exploitation period of the LSP. Results of this review along with other criteria, will used during the Pre- Ship Evaluation (PSE) to determine if the instrument is ready for shipment to AFRC Building 703 for tests and integration on the Observatory.

The LSP Kickoff Review is chaired by the SOFIA Science and Mission Operations (SSMO) Director. The SSMO Director forms a review panel to assess whether the LSP Kickoff Review success criteria have been met. The review panel is composed of SOFIA staff members including the SOFIA SI Development Manager, Project Scientist, Facility Scientist, Observatory Systems Director, and SSMO Director.

After completing the LSP Kickoff Review, minutes of the meeting are to be published and distributed. The minutes are to contain at least the presentations, documentation of any decisions made, attendees, and action items. Closure date and person responsible for addressing the action are to be identified.

Table B-4 – Entrance /Success Criteria for the LSP Kickoff Review

Entrance Criteria
1. A preliminary agenda and chart content for the LSP Kickoff Review have been agreed to by the instrument developer and SOFIA SI Development Manager, SSMO Director and Project Scientist prior to the review.
2. The LSP Kickoff Review technical products including the Science and performance requirements, the Science and performance requirements compliance matrix and the commissioning plan identified in Section 3 and Appendix A have been delivered by the instrument developer to the SOFIA program 3 weeks prior to the review.
3. All scientific performance requirement verification activities of the instrument that can be completed in a laboratory environment have been successfully completed, and planning and preparation for all remaining activities has been completed.
Success Criteria
1. Instrument meets the originally proposed science performance requirements defined in the ICS Report, and any “as built” deviations or limitations have been identified.
2. Instrument ready to conduct science operations on-board SOFIA
3. Risks are understood and have been credibly assessed.
4. The operational concept is technically sound, and the SI concept of operations has been updated to reflect the “as built” design.

5. All RFIs, RFAs, TBD and TBR items against the design have been resolved and dispositioned, or, if not, an adequate plan exists for timely resolution of open items.
6. Instrument commissioning is well planned and can be completed in a timely manner.
7. Preliminary LSP observing plan is reasonable and deemed achievable.

3.7 Pre-Shipment Evaluation (PSE)

The purpose of the PSE is to demonstrate that the instrument is ready for shipment to AFRC Building 703 for tests and integration on the Observatory.

The PSE is chaired by the SOFIA SI Development Manager. The SI Development manager forms a review panel to assess whether the PSE success criteria have been met. The review panel is composed of SOFIA staff members including the SOFIA SI Development Manager, SOFIA Operations Director, SOFIA Chief Engineer, SE&I Lead, SIAT Lead, and SOFIA S&MA Lead.

After completing the LSP Kickoff Review, minutes of the meeting are to be published and distributed. The minutes are to contain at least the presentations, documentation of any decisions made, attendees, and action items. Closure date and person responsible for addressing the action are to be identified.

Table B-5 – Entrance /Success Criteria for the PSE

Entrance Criteria
1. All RFIs/RFAs/action items from FRR have been dispositioned or a clear path for dispositioning exists.
2. The PSE Review technical products identified in Section 3 and Appendix A, KDP D have been delivered by the instrument developer to the SOFIA program.
3. Success criteria of LSP Kickoff review has been met, and the instrument is capable of fulfilling its scientific performance.
4. All verification activities of the instrument that can be completed in a laboratory environment have been successfully completed, and planning and preparation for all remaining activities has been completed. This includes ICD verification, and SI System Specification (SE01-2028) verification.
5. All necessary airworthiness documentation has been delivered three weeks prior to this meeting.
6. The instrument drawing package is current and correct (matches the actual hardware).
7. Instrument operational procedures are on track to be approved in advance of execution.
8. Subsequent laboratory testing of the SI has been planned and coordinated with the Building 703 lab manager.

9. SI shipping plan details have been coordinated with ARFC Building 703 lab manager.
10. SI developer has coordinated with SOFIA program on plan for SI receiving and storage in Building 703.
Success Criteria
1. The instrument is on track for airworthiness approval, ICD verification, SI System Specification (SE01-2028) verification, and scientific performance requirements verification. Open issues are addressed in RFIs/RFAs or action items.
2. Airworthiness approval status is adequate for shipment.
3. Instrument operational procedures listed in the Operations Manual are on track to be approved in advance of execution.
4. Planning and preparation for shipping and subsequent laboratory testing at Building 703 is complete.

3.8 Pre-Install Review (for SIs prior to transfer to NASA)

The SI Pre-Installation Review (PIR) is held prior each installation of the instrument onto the aircraft. It can be held as early as two weeks prior to installation.

The SOFIA Operations Director appoints the SSMO responsible instrument engineer to lead the PIR. The list of stakeholders who are required to be represented and polled for concurrence with proceeding to installation includes the SOFIA Operations Director, SI Principal Investigator, SSMO Mission Operations Manager, SSMO Ground Operations Manager, SSMO Lab Supervisor, SE&I Lead, SIAT Lead, SOFIA Safety Lead, SOFIA S&MA Lead, SOFIA SI Development Manager, a Flight Systems representative, and a Telescope Assembly (TA) representative.

Note, success criteria items #10 through #18 are not the sole responsibility of the SI developer, and require coordination with SOFIA staff.

Table B-6 – Entrance /Success Criteria for the PIR

Entrance Criteria
1. Instrument developer has provided instrument status input to NASA prior to the Pre-Install Review; Mission Operations will prepare and distribute presentation charts and materials to cognizant participants prior to the review.
2. The PIR technical products identified in Section 3 and Appendix A, KDP E have been delivered by the instrument developer to the SOFIA program three weeks prior to each PIR.
3. All RFIs/RFAs/action items from the PSE have been dispositioned.

4. Functional testing of the instrument at Building 703 has been successfully completed (or is on schedule to be completed) and the SI is ready for installation (or is on track to be ready for installation). a. Instrument warm and cold functional checks have been completed. b. Instrument cryogen hold time has been verified (if instrument uses liquid cryogens)
5a. (Initial PIR) The instrument has obtained airworthiness approval. 5b. (Subsequent PIRs) A determination has been made as to whether there is any delta airworthiness qualification required prior to installation, and if there is, a plan exists to perform that qualification prior to installation.
6a. (Initial PIR) All ICD verification has been successfully completed, or a plan exists to complete all required verification prior to installation. 6b. (Subsequent PIRs) A determination has been made as to whether there is any delta ICD verification required prior to installation, and if there is, a plan exists to perform that verification prior to installation.
7a. (Initial PIR) All SI cart qualification (load testing) has been successfully completed, or a plan exists to complete all required qualification prior to installation 7b. (Subsequent PIRs) A determination has been made as to whether there is any SI cart delta qualification (load testing) required prior to installation, and if there is, a plan exists to perform that qualification prior to installation.
8. A proposed installation schedule has been developed.
9. All installation procedures are approved, or if not, a plan exists to obtain approval prior to installation.
10. A physical inspection of the safety/airworthiness related external features of the instrument has been successfully completed, or a plan exists to perform the physical inspection prior to installation.
11. The Instrument Configuration sheet describing the current configuration of the instrument (anything that might change from one flight or flight series to another -- e.g., filters, grisms, channel configuration, software) is current and complete.
Success Criteria
1. The SI is ready for installation.
2a. (Initial PIR) The instrument has obtained airworthiness approval. 2b. (Subsequent PIRs) Any required delta airworthiness qualification has been completed, or there is an agreed-upon forward action(s) required to be completed prior to installation.
3a. (Initial PIR) All ICD verification has been successfully completed, or there is an agreed-upon plan to complete all required verification prior to installation. 3b. (Subsequent PIRs) Any required delta ICD verification has been completed, or there is an agreed-upon forward action(s) required to be completed prior to installation.

4a. (Initial PIR) All SI cart qualification (load testing) has been successfully completed, or there is an agreed-upon plan to complete all required qualification prior to installation. 4b. (Subsequent PIRs) Any required SI cart delta qualification (load testing) has been completed, or there is an agreed-upon forward action(s) required to be completed prior to installation.
5. The installation schedule has been agreed to and is achievable.
6. All installation procedures are approved, or if not, agreed-upon forward actions exist to obtain approval prior to installation.
7. A physical inspection of the safety/airworthiness related external features of the instrument has been successfully completed, or a plan exists to perform the physical inspection prior to installation.
8. The Instrument Configuration sheet describing the current configuration of the instrument and any instrument software changes from the prior flight series of the instrument, is current and complete.
10. Observatory is ready for instrument installation.
11. The Observatory hardware and software configuration has been communicated and is understood.
12. Personnel, procedures, and support equipment (e.g., the lift truck) are ready and available to support installation.
13. Critical lifts are known and support equipment and personnel are available.
14. The roles and responsibilities of team members during installation are understood.
15. Appropriate safety briefings are planned.
16. Tool control procedures have been communicated to the SI team.
17. The cryogen fill schedule (if applicable) has been coordinated.
18. All forward actions requiring completion prior to installation have been agreed to and will be tracked to closure.

3.9 LSP Review

Following commissioning, operation, maintenance, and configuration management of science instruments remain the responsibility of the PI institution, through the completion of the LSP exploitation period.

The purpose of the LSP Review is to demonstrate readiness of the SI to conduct science operations on-board SOFIA, the instrument meets the agreed to science performance requirements and to evaluate the final LSP observing plan for the exploitation period of the LSP.

The LSP Review is chaired by the SOFIA Science and Mission Operations (SSMO) Director. The SSMO Director forms a review panel to assess whether the LSP Review success criteria have been met. The review panel is composed of SOFIA staff members including the SOFIA SI Development Manager, Project Scientist, Facility Scientist, Observatory Systems Director, and SSMO Director.

After completing the LSP Review, minutes of the meeting are to be published and distributed. The minutes are to contain at least the presentations, documentation of any decisions made, attendees, and action items. Closure date and person responsible for addressing the action are to be identified.

Table B-7 – Entrance /Success Criteria for the LSP Review

Entrance Criteria
1. The SI developer has successfully completed the previous planned milestone reviews, RFIs/RFAs have been dispositioned, and plans to complete open work are defined.
2. A preliminary agenda, instructions to the review team and chart content for the LSP Review have been agreed to by the instrument developer/PI, SOFIA SI Development Manager, SSMO Director and Project Scientist prior to the review.
3. The LSP Review technical products including the commissioning report and the Legacy Science Program (LSP) Observing Plan part of the Commissioning plan (if revised) as identified in Section 3 and Appendix A have been delivered by the instrument developer to the SOFIA program 3 weeks prior to the review.
4. Instrument commissioning is complete.
Success Criteria
1. SSMO staff are ready to support the SI.
2. SI capabilities and operating modes have been successfully characterized in flight and performance limitations have been determined.
3. Risks are known and manageable.
4. TBD and TBR items are resolved.
5. Commissioning report and deliverables are complete and reflect the delivered SI.
6. Final LSP observing plan is deemed achievable.

3.10 Pipeline Acceptance Review (PAR)

The purpose of this review is to ensure the science data pipeline has been completed, any final modifications have been made, and it is ready for processing data that will be collected by observers during operations.

The PAR is chaired by the SOFIA SI Development Manager. The SOFIA SI Development Manager forms a review panel to assess whether the PAR success criteria have been met. The review panel is composed of SOFIA staff members including the SOFIA SI Development Manager and SOFIA Pipeline Development Lead.

After completing the PAR, minutes of the meeting are to be published and distributed. The minutes are to contain at least the presentations, documentation of any decisions made, attendees, and action items. Closure date and person responsible for addressing the action are to be identified.

Table B-8 – Entrance /Success Criteria for the PAR

Entrance Criteria
1. A preliminary agenda, instructions to the review team and chart content for the PAR have been agreed to by the instrument developer and SOFIA SI Development Manager prior to the review.
2. The SOFIA pipeline team has received all the necessary deliverables to allow them to complete development of the data reduction pipeline and calibration.
3. The SI team has provided any updates generated as a result of the in-flight performance. This requires new modules or updated parameters or algorithms, to be generated
Success Criteria
1. Data reduction pipeline for the instrument is complete and is on track to be available to users prior to the Acceptance Review.

3.11 Operations Acceptance Review (OAR)

The acceptance review can be completed at any time after the LSP review. NASA can commit to formally accept responsibility for operating the instrument any time after the OAR, even during the SIs LSP exploitation period, with the understanding that, operation, maintenance, and configuration management of science instruments remain the responsibility of the PI institution, through the completion of the LSP exploitation period. Once the LSP exploitation period is complete, these responsibilities will be transferred to the SOFIA program. A delta OAR may be required, only if the SI was physically modified, during the LSP exploitation period.

The SI Operations Acceptance Review is co-chaired by the SOFIA Observatory Systems Director and the SOFIA Project Scientist. The co-chairs form a review panel to assess whether the SI Acceptance Review success criteria have been met. The review panel is composed of voting SOFIA staff members including the SOFIA SI Development Manager, SOFIA Project Scientist, Facility Scientist, SOFIA Observatory Systems Director, SMO Director, SOFIA Operations Director, SOFIA Chief Engineer, SOFIA S&MA Lead, and the Program Planning and Controls Lead. Non-voting panel members include the Mission Operations Manager and Science Planning and Instrument Support Manager.

After the successful completion of the OAR, the formal SI Operations Acceptance process begins.

Table B-9 – Entrance /Success Criteria for the OAR

Entrance Criteria

1. The SI developer has successfully completed the previous planned milestone reviews, RFIs/RFAs have been dispositioned, and plans to complete open work are defined.
2. A preliminary agenda, instructions to the review team and chart content for the OAR have been agreed to by the instrument developer and SOFIA SI Development Manager prior to the review.
3. The OAR technical products identified in Section 3 and Appendix A, KDP F have been delivered by the instrument developer to the SOFIA program, three weeks prior to the OAR.
4. SSMO staff are familiar with the operation and maintenance of the instrument.
Success Criteria
1. The SI is ready to be made available to the general science community
2. Associated documentation deliverables are complete and reflect the delivered system
3. SI Software documentation is compliant with the SOF-NASA-PLA-PM20-2011; SOFIA Software Management Plan
4. SSMO staff are trained in the operation and maintenance of the instrument, or a plan exists to complete this training in a timely manner.

Appendix C - SI Airworthiness Certification Criteria

While science instrument development and construction is ongoing, the deliverable documentation items are crucial for the SOFIA Science Instrument Airworthiness Team (SIAT) to begin the airworthiness assessment. Compliance with the requirements for safety and airworthiness as listed in the *SOFIA Science Instrument System Specification* (SOF-AR-SPE-SE01-2028) is mandatory. In addition, prior to shipment, the SIAT will verify compliance with airworthiness requirements. Here is the list of what the SIAT will need to verify for providing and airworthiness certification recommendation to the NASA AFRC Technical Briefing Committee:

1. Provision of all deliverable documents relevant to airworthiness assessment as listed in Section 2, Section 3, and Appendix A.
2. Compliance with relevant ICDs (SCI-US-ICD-SE03-2027, SOF-DA-ICD-SE03-051, SOF-DA-ICD-SE03-2015) for total equipment weight, center of gravity, and overturning moment of populated PI Rack and Counterweight Racks (Structure analysis & Drawings).
3. Proper affixing of hardware to Counterweight and PI Racks in accordance with worst case loading conditions defined by the Ultimate Load Factors in the *Science Instrument System Specification* (SOF-AR-SPE-SE01-2028).
4. Identification of critical structures (Structure analysis).
5. Structural analysis showing positive margin of safety for all critical structure elements (including those that are part of the pressure boundary) (Structure analysis).
6. Containment of potentially loose hardware within the science instrument assembly and equipment racks.
7. Successful completion of relevant analysis, and qualification and acceptance pressure tests for cryogen reservoirs and other articles that are uniquely designed pressure elements in accordance with SOF-AR-SPE-SE01-2028 requirements (Analysis and Test report).
8. Material specifications and stress testing of optical window materials that are part of the pressure boundary in accordance with SOF-AR-SPE-SE01-2028 requirements (Material specifications sheet & stress test report).
9. Hazard reports which identify hazards inherent with the design and operation of the science instrument.
10. Listed and verified mitigations of hazards including risk assessment (Hazard & Risk assessment analysis).
11. Suitable application of external fastener retention to avoid foreign object damage (FOD) (this will be included in the IFR/FFR chart package and verified by inspection).
12. Certified Material Test Report (CMTR) documents for all materials and fasteners used with the critical structure of the instrument and all equipment mounted in equipment racks.
13. Analytical proof that cryogen relief system will withstand a loss of vacuum.
14. Manufacturer certification records for all pressure relief devices.
15. Completion of safety critical welds by a certified welder (Welding analysis/report).
16. Inspection of safety critical welds by a certified weld inspector.
17. Substantiation that breathable oxygen levels will remain above OSHA minimum when total cryogen volume is depleted due to loss of vacuum (test report).
18. Proper selection of wires for electrical load (Electrical drawings).
19. Ample over-current and over-voltage protection (Electrical design reviews IFR/FFR).
20. Protection from power loss or surges (Electrical drawings).

21. Verification of no polyvinylchloride (PVC) insulated electrical wires exist as specified by SOF-AR-SPE-SE01-2028, or where PVC is unavoidable, these wires are either replaced by suitable polytetrafluoroethylene (PTFE) insulation or wrapped with Teflon and then shrouded in Nomex (Physical inspection).
22. Provision of Nuclear Regulatory Council (NRC) license for any radioactive materials necessary to operate the science instrument.
23. Analysis showing that any pressure coupler interfacing with the hard points on the Gate Valve Pressure Plate (GVPP) does not exceed the limit or ultimate loads defined in Telescope Assembly/Science Instrument Mounting Interface (SOF-DA-ICD-SE03-037, paragraph 4.10.1).
24. Evaluation of potential electromagnetic interference with aircraft and observatory systems (EMI/EMC test plan & test report).
25. All discrepancies (non-conformances, anomalies, failures, “cannot duplicates,” etc.) are fully understood. Corrective actions are completed, and plans and preparations for any required follow-on actions are completed. All non-compliances and non-conformances have approved deviations or waivers.

Appendix D – NASA Ames Research Center, Electrical, Electronic and Electromechanical (EEE) Best Practices for SOFIA SI Development

1.0 PURPOSE

This electronic part guide provides the SOFIA science instrument (SI) development community a basic set of guidelines that will lead to the development of instruments that are safe, reliable, serviceable and low in the costs of maintenance/operation. The guiding principle here is to improve the quality and consistency of the SOFIA science instruments that are delivered to the project office without incurring undue cost burden and schedule delay, i.e. trying to achieve a good balance between the instrument development costs and operational efficiency.

2.0 SCOPE

This document provides a set of guidelines that are based on best practices being followed at NASA Ames Research Center (ARC) for electronic parts management and control. Most of the content is derived from the JSC ISS Class 1E Management Directive [1] and APR 8730.2, Ames EEE Parts Control Requirements [2], due to their similarities in the intents and purposes with the SOFIA SI development effort.

3.0 ELECTRONIC PARTS MANAGEMENT AND CONTROL

3.1 Parts Acquisition

3.1.1 Procurement

Parts shall be procured from original parts manufacturers or their authorized distributors where Certificate of Conformance (CoC) can be obtained as needed. Plan for adequate electronic part procurement lead times in support of the manufacturing and delivery schedules.

3.1.2 Traceability

All electronic parts purchased shall be traceable to a specific manufacturer, part number, and lot number or lot date/trace code (LDC). In addition, parts requiring serial numbers should have traceability to test data associated with the same lot or individual parts.

3.1.3 Receiving and Inspection

After receiving electronic part shipments, the person(s) in charge of part procurement should check and verify the accuracy of the shipments. For instance, visually inspecting the parts to make sure the part numbers, LDC, pin count and package type match those on the order lists.

3.1.4 Handling and Storage

Parts shall be handled with proper ESD (Electrostatic Discharge) care and be stored in properly controlled containers so that they are not exposed to excessive humidity, light or temperature extremes. Visually inspect parts for obvious damages or defects before putting them in BOM (Bill of Materials) kits for circuit board assembly work.

3.1.5 Record Keeping

Parts list for each electronics subsystem should be kept and updated as necessary, i.e. there should be some type of configuration management on the parts since the as-built part list may differ from the as-design list.

3.2 Counterfeit Parts Prevention

Counterfeit parts, especially in the electronic world, have become a common and serious issue for electronics developers; hence, some basis steps, such as the ones listed below, should be followed

in order to minimize the risk of counterfeited parts entering the SI leading to serious safety hazard, failures and damages in them.

3.2.1 Purchasing

Only buy directly from manufacturers or their authorized distributors, require proof of traceability to original manufacturer, verify manufacturers have guaranteed methods to destroy scrapped parts, and buy adequate stock of lifetime buys for parts that are being discontinued. Purchasing from independent distributors should be avoided, and when it is unavoidable due to discontinued productions, request the original part manufacturer to authenticate documentations received from the distributor.

3.2.2 Contract

Purchase orders or contracts should include applicable clauses that hold suppliers liable for counterfeit parts; counterfeiting is a federal crime.

3.2.3 Receiving

All parts shall be subjected to inspection by the receiving person, who should visually inspect parts, pay attention to labels, misspelling, omissions, and ensure lot date codes matching that on the labels. One simple way to verify, if parts are suspected to be counterfeits, is to secure package and die photographs from original manufacturers for comparisons.

3.2.4 Control

Identify and quarantine suspect counterfeit parts, followed by confirmation whether the parts are authentic or counterfeit. Once a part is confirmed counterfeit, all potential counterfeit units shall be on hold in storage and identify installed counterfeit units pending disposition by appropriate authorities. Destroy and/or submit to investigation authorities confirmed counterfeit parts. Counterfeit parts should only be returned to suppliers under controlled conditions so as to prevent their re-entry into the supply chain.

3.2.5 Reporting

Suspect counterfeit reports that specifically address the suspect counterfeit products and materials can be submitted to GIDEP (GOVERNMENT - INDUSTRY DATA EXCHANGE PROGRAM) or law enforcement authorities.

4.0 REFERENCES

1.) APR 8730.2: Ames EEE Parts Control Requirements
2.) Class 1-E Flight Hardware Development Policy, ISS Management Directive, NASA JSC

Appendix E – Acronyms

Acronyms and abbreviations are listed in alphabetical order.

AC	Alternating Current
ADR	Adiabatic Demagnetization Refrigerator
AFRC	NASA Armstrong Flight Research Center
AFSRB	Airworthiness & Flight Safety Review Board
ANSI	American National Standards Institute
AOR	Astronomical Observing Requests
AOT	Astronomical Observing Templates
APR	Ames Procedural Requirement
ARC	NASA Ames Research Center
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing & Materials
AW	Airworthiness
AUX	Auxiliary
AWS	American Welding Society
B703	Building 703 (AFRC)
BOM	Bill of Materials
C	Celsius
CA	California
CAD	Computer Aided Design
CDR	Critical Design Review
Cert	Certificate of Conformance or Certification
c.g.	Center of Gravity
CG	Center of Gravity
CMTR	Certified Material Test Report
CoC	Certificate of Conformance
COTS	Commercial Off-The-Shelf
CSI	Critical Safety Item
CW	Counterweight
CWR	Counterweight Rack
DCS	Data Cycle System
deg	Degree
DLR	German Aerospace Center, Deutsches Zentrum für Luft- und Raumfahrt
DSI	Deutsches SOFIA Institut
EEE	Electrical, Electronic and Electromechanical
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
F	Fahrenheit
FEM	Finite Element Model
FMECA	Failure Mode, Effects and Criticality Analysis
FPI	Focal Plane Imager
FFR	Final Formulation Review

FOD	Foreign Object Damage
FSI	Facility Science Instrument
ft	Feet
FY	Fiscal Year
GFE	Government Furnished Equipment
GIDEP	Government-Industry Data Exchange Program
GS	Ground Safety
GSE	Ground Support Equipment
GTAW	Gas Tungsten Arc Welding
GTO	Guaranteed Time Observation
GVPP	Gate Valve Pressure Plate
He	Helium Gas
hr	Hour
HR	Hazard Report
Hz	Hertz
I&T	Integration & Test
ICD	Interface Control Document
ICS	Instrument Concept Study
IFR	Initial Formulation Review
IGES	Initial Graphics Exchange Specification
IMF	Instrument Mounting Flange
IMS	Integrated Master Schedule
in	Inch
IR	Infrared
ISO	International Organization for Standardization
ISS	International Space Station
JSC	NASA Johnson Space Center
KDP	Key Decision Point
LDC	Lot Date/Trace Code
LDEM	Lifting Device Equipment Manager
LHe	Liquid Helium
LN2	Liquid Nitrogen
LOV	Loss Of Vacuum
LSP	Legacy Science Program
MA	Mission Assurance
MD5	Message-Digest Algorithm
MPL	Master Parts List
MIL-STD	Military Standard
μm	micrometer; micron
min	Minute
mm	millimeter
MNOP	Maximum Normal Operating Pressure
MOPS	Mission Operations
MOU	Memorandum of Understanding
MPL	Master Parts List

MS	Margin of Safety
msec	millisecond
N/A	Not Applicable
N2	Nitrogen Gas
NAS	National Aerospace Standards
NASA	National Aeronautics and Space Administration
NASA-STD	NASA Standard
NDE	Nondestructive Examination
NDT	Nondestructive Testing
NGSI	Next-Generation Science Instrument
NPR	NASA Procedural Requirement
NRA	NASA Research Announcement
NRC	Nuclear Regulatory Council
NSPIRES	NASA Solicitation and Proposal Integrated Review and Evaluation System
OAR	Operations Acceptance Review
OCCR	Observatory Configuration Change Requests
OCCB	Observatory Configuration Control Board
OSHA	Occupational Safety and Health Administration
PAR	Pipeline Acceptance Review
PCA	Physical Configuration Audit
PDR	Preliminary Design Review
PI	Principal Investigator
PIF	Pre-Flight Integration Facility
PIR	Pre-Install Review
PIS	Platform Interface System
PM	Project Management
Pmax	Maximum Pressure
PPBE	Planning, Programming, Budgeting, and Execution
PR	Proposal Review
PRR	Pipeline Readiness Review
PSE	Pre-Shipment Evaluation
PSI	Principal Investigator Science Instrument
psi	pounds per square inch
psid	pounds per square inch differential
PTFE	Polytetrafluoroethylene
PVC	Polyvinyl chloride
PVS	Pressure Vessel Systems
QA	Quality Assurance
Rev	Revision
RFA	Request for Action
RFI	Request for Information
ROSES	Research Opportunities in Space and Earth Sciences
S&MA	Safety & Mission Assurance
SAT	Standard ACIS Text
SCL	SOFIA Command Language

SE&I	Systems Engineering & Integration
sec	Second
SHA	Secure Hash Algorithm
SI	Science Instrument
SIAT	Science Instrument Airworthiness Team
SIC	Science Instrument Cart
SIDAG	Science Instrument Development Advisory Group
SIL	Systems Integration Laboratory
S&MA	Safety and Mission Assurance
SMD	Science Mission Directorate
SMO	Science Mission Operations
SObRR	SOFIA Observatory Readiness Review
SOFIA	Stratospheric Observatory For Infrared Astronomy
SOW	Statement of Work
SSA	System Safety Assessment
SSL	SOFIA Science Laboratory
SSMO	SOFIA Science and Mission Operations
SSWG	System Safety Working Group
STD	Standard
STEP	Standard for the Exchange of Product model data
TA	Telescope Assembly
TAAS	Telescope Assembly Alignment Simulator
TAAU	Telescope Assembly Alignment Unit
TBD	To Be Determined
TBR	To Be Reviewed
TCP/IP	Transmission Control Protocol/Internet Protocol
UPS	Uninterruptible Power Supply
US	United States
USRA	Universities Space Research Association
V	Volt
V&V	Verification & Validation
VAC	AC Voltage
VDC	DC Voltage
VDD	Version Description Document
VPN	Virtual Private Network
W	Watts
WBS	Work Breakdown Structure