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Test Plan

GCPS Task 7, Subtask 7.1
IHM Development

Cooperative Agreement NCC1-193

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Rockwell Aerospace
Space Systems Division

NORTHROP GRUMMAN

Rockwell Aerospace
North American Aircraft

Table of Contents

1.0 OBJECTIVE

The overall objective of Task 7 is to identify cost-effective life cycle integrated health management (IHM) approaches for a reusable launch vehicle's primary structure. Acceptable IHM approaches must: eliminate and accomodate faults through robust designs, identify optimum inspection/maintenance periods, automate ground and on-board test and check-out, and accommodate and detect structural faults by providing wide and localized area sensor and test coverage as required. These requirements are elements of our targeted primary structure low cost operations approach using airline-like maintenance by exception philosophies.

This development plan will follow an evolutionary path paving the way to the ultimate development of flight-quality production, operations, and vehicle systems. This effort will be focused on maturing the recommended sensor technologies required for localized and wide area health monitoring to a Technology Readiness Level (TRL) of 6 and to establish flight ready system design requirements. The following is a brief list of IHM program objectives.

- Design out faults by analyzing material properties, structural geometry, load and environment variables and identify failure modes and damage tolerance requirements.

- Design in system robustness while meeting performance objectives (weight limitations) of the reusable launch vehicle primary structure.

- Establish structural integrity margins to preclude the need for test and checkout and predict optimum inspection/maintenance periods through life predicition analysis.

- Identify optimum fault protection system concept definitions combining system robustness and integrity margins established above with cost effective health monitoring technologies.

- Use coupons, panels, and integrated full scale primary structure test articles to identify, evaluate and characterize the preferred NDE/NDI/IHM sensor technologies that will be a part of the fault protection system.

2.0 BACKGROUND

2.1 IHM Overview Integrated Health Management for SSTO systems will provide the capability to efficiently perform checkout, testing and monitoring of vehicles and ground infrastructure. Critical SSTO issues to assure reusability, structural integrity and cost effective test and prognosis are addressed through health management design methodologies, tools and technologies. Future IHM efforts will integrate the design and analyses, development tests, and vehicle and ground based systems to provide integrity assessment, reliability prediction, and maintenance on exception capability. Health management trades will be applied during all phases of system development tasks to insure component and integrated vehicle system faults are avoided or accommodated in a cost effective solution. In addition to component level data, health monitoring integrates vehicle performance and environment factors that will influence safety margins, reliability, damage tolerance, and component life consumption. In addition to supporting nominal mission turnaround, additional capabilities may be required to support repair and recertification following off-nominal mission events or contingency aborts.

2.2 NRA8-12 Advanced Structure IHM Integration. This development plan supports NCC2-9002, Technology Area 2 (TA2) Graphite Composite Primary Structure, Task 7 (IHM). Other IHM technology areas concurrently being investigated by Rockwell under NRA8-12 funding are; NCC2-9001 "Reusable Hydrogen Cryogenic tank System IHM" and NCC2-9003 "Lightweight Durable Thermal Protection System IHM". Coordination between the three tasks will be provided by SSD and each are elements of an overall structural IHM system that will be developed and demonstrated in a follow-on program.

2.3. TA2 Primary Structure Task 7 IHM Integration. There are three primary structural elements that will be developed in TA2. These are the intertank structure, the thrust structure, and the wing/aeroshell structure. Typical faults that will have to be addressed in each of these elements are structural flaws (voids, pits, cracks, etc.), delaminations, and wing/TPS debonds. Upon completion of the robustness and health monitoring concept definitions (impacts, stress loads, etc.), conventional and advanced sensor technologies will be investigated for application to the identified fault modes and monitoring capability.

The following potential Non-Destructive Evaluation/Inspection (NDE/I) technologies will be evaluated and characterized (if applicable) on coupon and panel level tests during the program: infrared thermography, fiber optics, ultrasound, acoustic energy monitoring, and laser acoustic emissions. Tests will focus on those technologies that are the most economically capable of wide-area inspections for production and field applications with the major emphasis on operations turnaround requirements. Technologies will be evaluated to locate and quantify anomalies in integrated assemblies that reflect operational configurations, such as debonds between layers of thermal protection and substrate, substrate flaws and delaminations.

Upon completion of the coupon/panel level tests, the preferred sensor technologies will be designed into and applied to the Wing/Aeroshell and Intertank, and Thrust Structure Full Scale Test Articles (FSTA). During full scale testing at LaRC, the NDE/I sensor technologies will be validated and demonstrated in an integrated system environment.

2.4 The IHM activities are planned so that they complement and build on the other tasks in TA2. Using interactive designs and trade studies will allow an efficient and positive flow of data from IHM and the rest of the program.

3.0 GENERAL REQUIREMENTS

The established policies and practices of the testing facility will dictate general requirements. If a particular test requires deviation from the performing test facility's test requirements, an exception must be established.

4.0 DETAILED REQUIREMENTS

The detailed requirements outlined below are by sub tasks.

4.1 Generate the Program IHM Development Plan

4.1.1 This development plan shall provide IHM design and system requirements and shall identify system faults that will have to be monitored/managed during operations and will establish preliminary test plans to be used 1) during Intertank, Thrust Structure and Wing/Aeroshell building block program using coupons and panels as IHM test specimens and 2) during the Full Scale Test Article structural tests at LaRC. This plan will be updated quarterly and serve to meet the Quarterly Report Requirements of the Program.

- Estimated Completion of the initial Plan is: 02 September 1994
- Initial Task effort will run from May through August 1994.
- Primary Responsibility: Space Systems Division Rockwell Aerospace

4.1.2 Approach

This development plan will be written by IHM personnel from LaRC, NOC, and SSD and will outline tasks providing requirements, approaches and detailed test plans using program hardware. The IHM development plan will be a dynamic document and lessons learned during sensor selection will influence full scale test article testing at the end of this program. As a result, test plans for the activities will initially be general and become more specific as the effort progresses.

A Structural IHM System Definition Statement will be developed that will identify potential fault modes and the probability of their occurrence during operations. This statement will be the driving function for all TA2 IHM efforts. This statement will describe operations requirements and will identify failure mode characteristics (*i.e.*, flaw size, location, orientation, structural integrity requirements, tolerance limits, etc.) for the three structural configurations.

In order to establish the fault set, an integrated database will be developed to support our reliability analysis based on conceptual mission, vehicle and structure component designs. Material and structural test data will be evaluated by the IHM team and integrated in the database to validate design and material characteristics used for reliability prediction. During the building block program, the structural fault set will be updated and continually evaluated for coverage.

The team's structural reliability analytic methods and Finite Element Analysis tools will be applied to material and structural concepts to generate the data for this database and to help guide the selection of advanced materials, design constraints and processes. The structural analysis methodology will identify the significant material properties, structural geometry, load and environment variables for analysis, test design and modeling. Test design and planning will include methods to address long term effects of individual and synergistic factors, such as, physical aging, chemical aging, extended exposure to extreme temperatures, vacuum and radiation. Fracture mechanics analysis will be incorporated to predict faults and damage effects and define tolerance requirements. This fracture mechanics methodology will be coupled with structural analysis methodology and is verified by conducting accelerated structural fatigue tests on subscale test articles. Structural elements, panels and components will be designed, fabricated and tested under combinations of thermal, mechanical, and internal pressure loads to verify material selections, structural design concepts and analytical predictions.

The data for the IHM database will also be supplied by the other tasks' material characterization efforts that include: static and dynamic strength, thermal properties, durability, material fabrication and repair processes, material and chemical compatibility, environment and aging effects. Selected materials will be used to fabricate sub-element samples to test fabrication and repair methods and verify design factors and the IHM effort will utilize these samples for sensor selection when they become available.

4.1.2.c The analysis and test activities will generate a model for initial structural element inherent reliability and provide a mechanism for continuous update and predication of remaining operational life of a structural element. This model for remaining life prediction is the basis of the Structure Health Management concept. Coverage of design limit and life measurements will include mission and ground operations data, in-flight and ground operations fault and damage event detection and ground tests. In-situ sensors for health management will be added only where adequate coverage is not provided through other sources.

4.2 Equipment and Sensor Screening

4.2.1 Requirement

Sensing technologies shall be evaluated for both ground and in-flight application. Sensing and scanning technology inputs will be solicited from government agencies (NASA, DOD, national labs) as well as the aerospace and commercial industries. Evaluation criteria shall be driven by system operational capability and sensor development cost, operations costs and benefits, maturity and availability.

- Estimated Completion Date: 04 November 1994
- Task effort will run from June through October 1994.
- Primary Responsibility: SSD

4.2.2 Approach

Analysis and sensor technology screening will be performed in conjunction with the Structural IHM System Definition Statement. Many sensors will be evaluated through analysis in an attempt to avoid undue elimination of a technology without fully considering its potential application to this program. A combination of sensors will be needed to detect and evaluate all the failure modes because each NDE/I sensor technology has a specific capability and applicability. Additionally, the three Gr/Ep primary structures being demonstrated under the TA2 effort will provide differing requirements based on their respective failure modes. The sensor screening process shall be evaluate both NDE conventional and advanced sensor technologies.

Conventional are those NDE technologies that are available and/or established methods, techniques, off the shelf equipment and training materials. Examples include but are not limited to: ultrasonic, eddy current, x-ray, penetrant, magnetic particle, visual and microwave.

Ultrasonic Inspection - Contact ultrasonic technology utilizes piezoelectric transducers to transmit and receive data. Transducers are placed on the inspection surface and used individually (pulse-echo) or in pairs (through transmission). When an individual transducer is used in pulse-echo mode, access from only one side is required. The transducer pulses sound energy into the specimen and listens for an echo. This method is commonly used for small area inspections. The through transmission method requires access to both sides of the specimen and meets the needs of process control monitoring during the manufacturing and fabrication of the graphite primary structure. Tests will evaluate capability and effectiveness and detect and quantify flaws and damage such as porosity, cracks and delaminations. Contact ultrasonic inspection technology typically requires a couplant such as water, gel, or epoxy to provide adequate energy transmission into the material. Specialized air scan systems may also be evaluated for capability to locate and quantify anomalies in integrated assemblies such as disbonds between layers of insulation and substrate. The pulse-echo method will be screened for IHM applicability.

Eddy Current - Eddy Current inspection is an electromagnetic process that measures minute changes in the magnetic field (due to eddy currents in the test material) between two current carrying coils. The magnetic field will be changed if the distance to or thickness of the measured conducting medium changes. Due to low conductivity, Gr/Ep materials do not respond well to eddy current examination. Metal matrix composites also appear to respond to eddy current inspection. However, eddy current may not be a useful inspection technology for IHM of composite material structures unless adequate sensitivity can be demonstrated.

X-Ray Radiography - X-ray technology may be used as needed during manufacturing and fabrication to verify indications revealed by other NDE/I methods. X-ray is will not be screened for IHM applicability. Safety considerations rule it out as an IHM technology. Advanced radiographic techniques using computer enhancement to evaluate flaws in the materials and structures may be employed to determine structural integrity during fabrication and will be evaluated for assessing materials for flaws during post flight maintenance.

Dye Penetrant - Penetrant technology may be used as needed during manufacturing and fabrication but will not be screened as an IHM technology. Penetrant is a labor intensive technology used primarily on metals. The detection sensor is the operators' eyes. In addition, the development cost of automating this process is out of the scope of this project.

Advanced NDE technologies are those that build on the conventional NDE technologies and in some manner enhance the performance of the methods in either a generic or application specific manner. Examples include but are not limited to; acoustic emission sensors, Laser Based Ultrasonic (LBU), Fiber Optics, Shearography, Computed Tomography and Thermography. Usually these are technologies that offer a unique approach or application of state-of-the-art technology.

Acoustic Emission - Acoustic emissions are detected by attaching ultrasonic transducers to the surface of the material at strategic points to record the stress emissions generated within the structure. Low level sonic or ultrasonic emissions may be generated by stress relief at cracks and flaws under load resulting in local material deformation, degradation or damage, in response to structure impacts and as a result of leaks. (ref. 1) Emission in the structures generate characteristic pulses which can be monitored to identify the type of flaw, the location and the rate of growth. Acoustic Emission can be used to gather data during the manufacturing and test programs to establish baselines for the detection of flaws generated during flight. The data is gathered and reviewed by computer to monitor the integrity of the structures and to monitor the growth of anomalies. This versatile technology is used as a tool to study mechanical behavior of materials, as an NDT technique and as a quality control method. As an NDT method it is calibrated to a structure and then waits to detect and process low level events while the structure is under load.

Laser-Based Ultrasonic Inspection - Laser Based Ultrasonics is a non-contacting derivative of standard ultrasonic inspection. Ultrasonic pulse energy is introduced into the test specimen by pulses of light from a laser. The reflected or transmitted ultrasound pulse is detected with a fiberoptic interferometer that detects motion of the surface. Laser generated pulses typically have much lower energy that contact ultrasonics so frequency locking is used to filter the signal from the noise. This emerging technology will be screened for IHM applicability. Preliminary test results of a Gr/Ep panel using the Rockwell International LBU system shows positive results for IHM applicability.

Fiberoptics - Fiberoptic sensors are a novel method for determining the health or condition of composite structures. The optical fibers, which usually measure for stress or temperature, are imbedded into the composite structure. Continuous strain readings can be made along the length of the fiber based upon the return time of the strain signal. Temperature sensors usually have a series of nodes along the fiber length. These sensors provide wide area coverage and are compatible to harsh environments. They provide composite curing information and can provide continuous information during manufacture, testing and flight. The main drawback to these sensors is the difficulty in replacing them if they should fail.

Shearography - Shearography is a form of interferometry that uses a laser to acquire stressed and stress free images of the test item. The nonstressed image is added in real time to the stressed images to produce interference patterns, observable on a TV monitor, which indicate areas experiencing minute movements during the process. These patterns may be interpreted to indicate flaws such as cracks, delaminations, disbonds and other anomalies. Shearography appears to be most effective with flexible rather than stiff rigid materials.

Thermography - Thermography is a remote non-contacting method utilizing infrared imaging sensors for detecting a variety of surface and subsurface material defects and faults. Thermography will be evaluated for material inspection, fault detection and integrated assembly evaluations. Standard Thermography is performed by scanning the surface of a structure with an infrared (IR) video camera, which is capable of detecting small variations in temperatures, to image the thermal patterns of test articles. These variations may be recorded by video camera and stored either as a digital image in a computer or as video images on VCR tape. The images can be evaluated to ascertain if the patterns indicate anomalies such as disbonds, delaminations, cracks or other flaws. The image of a test object may be compared to a reference image to detect anomalies that can be highlighted. If the emissivity of the materials in the image are known, actual temperatures can be quickly and easily calculated. This technique is useful in any application where temperature or emissivity differences can be used as a discriminator. For example, surface pits and scratches act as blackbody radiators, appearing as bright spots or streaks on an otherwise darker image. Other techniques to enhance this effect and to render subsurface flaws visible utilize heating or cooling of the test panel from the back side to observe thermal leakage or non linearity, heating from the front to observe anomalies in thermal conductivity and observation of thermal patterns generated under vibration or pressure loading.

Test evaluations will include applications such as detection of surface cracks, scratches and pits. Material tests will be monitored to determine capabilities to detect internal faults as a result of heating caused by loading stress or friction at fault locations such as delaminations and subsurface cracks, voids and other flaws. Delamination and disbond fault detection tests will attempt to detect hot or cold spots caused when thermal conductivity is lost as the result of delaminations or other subsurface flaws. Evaluations will also include monitoring the tile surfaces of completed wing/aeroshell structures for moisture evaporation and TPS impact damage.

To gather data for sensor comparisons and selection of equipment and sensors, a Sensor Capability Classification Matrix (Table 4.2.2.b) will be developed. This will be a summarization of the aforementioned NDE/I technologies and their capabilities to detect faults in a Gr/Ep system. Work has been initiated on developing this matrix.

Table 4.2.2.b Sensor Capability Matrix

Comparison of Selected NDE Methods

Method	Properties (Sensed or Measured)	Typical Discontinuities Detected	Advantages	Limitations
X and Gamma Radiography	Changes in density from voids, inclusions, material variations, placement of internal parts.	Voids, porosity, inclusions, and cracks	Detects internal discontinuities; useful on a wide variety of materials; portable; permanent record	Cost; relative insensitivity to thin or laminar flaws such as fatigue cracks or delaminations which are perpendicular to the radiation beam; health hazard
Eddy current examination	Changes in electrical and magnetic properties caused by surface and near-surface discontinuities	Cracks, seams, laps, voids, and variations in alloy composition and heat treatment	Moderate cost; readily automated; portable; permanent record if needed	Conductive materials only; shallow penetration; geometry sensitive; reference standards often necessary.
Microwave examination	Anomalies in complex dielectric coefficient; surface anomalies in conductive materials	In dielectric's; disbonds, voids, and cracks; in metal surfaces; surface cracks	Noncontacting; readily automated; rapid inspection	No penetration of metals; comparatively poor definition of flaws

Ultrasonic Examination	Changes in acoustic impedance.	Cracks, voids, porosity, lamination, delaminations, and inclusions	Excellent penetration; readily automated; good sensitivity and resolution; requires access to only one side; permanent record, if needed.	Requires acoustic coupling to surface; reference standard usually required; highly dependent upon operator skill; relative insensitivity to laminar flaws which are parallel to the sound beam

To further assist in the selection of each method, the matrix will be expanded to cross-reference the technology capability with the faults that are to be identified. This matrix will be designed to help identify the most promising sensor technology to detect the potential fault modes. The matrix will be developed and documented during the NDE/I and sensor screening process.

During the screening process, the NRA8-12 team members, government agencies (NASA, DOD, national labs), aerospace and commercial industries will be contacted to gather promising NDE/I and sensor technologies for screening. Contacts have been initiated between SSD and several NDE/I and sensor technology vendors.

The NDE/I and sensor screening process will be run in conjunction with similar surveys for TA1 and TA3 and will use the Sensor Capability Classification Matrix criteria and the Structural IHM System Definition Statement. Literary searches will be conducted to obtain information on current NDE/I activities. This provides not only current background information but identifies key players in sensor application development. A literary bibliography will be maintained. Additionally, conferences will be attended or minutes obtained to stay abreast of technologies.

4.3 Component Level IHM Test (Panels)

4.3.1 Requirement

Characterize and evaluate conventional and advanced NDE/IHM sensor performance on coupons and panels with pre-induced faults that will simulate the Structural IHM System Definition Statement of inter tank, thrust structure and wing/aeroshell fault modes.

- Estimated Completion Date: 17 May 1996
- Task effort will run from February 1995 through April 1996
- Primary Responsibility: TBD

4.3.2 Approach

During primary composite structural testing for durability (fatigue) and damage tolerance (safety) a demonstration (of a particular material type and design under prescribed conditions) will be conducted to show that the structure can meet operational usage requirements. The experience base to date has shown that composite parts rarely fail during realistic fatigue testing. However, when test conditions are extended to explore failure mechanisms, delamination is observed to be the most prevalent life-limiting growth mode. Coupon and panel IHM tests will be developed to explore these life-limiting failure modes.

A general description of common composite failure modes (emphasizing Gr/Ep) will help in understanding the selection of target defects for IHM to focus on in this task. Unlike a metallic component where the fracture generates from a single crack, laminate composite failures come from a damage zone that is characterized by matrix cracking, fiber breakage, and delamination. The types and modes of failure depend on the load direction and fiber ply orientation. Most discussions on the issue of composite material failures separate the modes into two types; in-plane and out-of-plane-failures.

Gr/Ep in-plane failure modes, in either compression or tension, lead to fiber breakage and instability of adjacent fibers, thus weakening the structure and resulting in a delamination at the failure site. The fibers will kink before breaking when under compression. Under tension the fibers can randomly break becoming brittle or pulling out of the matrix causing the load to be transferred to adjacent fibers. As a result the matrix and fibers separate causing a delamination at the failure site.

When out-of-plane (interlaminar normal and shear originating from fuel pressures, air pressures or structural mismatches) stresses develop, failure can occur because of the mismatch in engineering properties between the fibers and matrix materials. The out-of-plane failure typically develops at structural discontinuities, such as free edges, holes, ply drops, bond joints, and bolted joints. (Reference 4.3-1). Regardless of whether these failure modes are in-plane or out-of-plane, a delamination will result. Since continuous fibers make up the fabric plies, delaminations usually occur between the plies.

Delaminations can also be found as "birth defects," or can be created due to foreign object impact. (Reference 4.3-2). "Birth defects" are caused during, or by, the manufacturing process and identified by an NDE method such as, ultrasonic, thermography, shearography or visual and the decision has been to let the flaw enter service.

Impact damage including foreign object impact can occur at any time. During a NASA funded Gr/Ep behavior study (Reference 4.3-3) the effects of impact damage, circular holes, and simulated delaminations (inserts) were investigated under static compression and cyclic compression load tests. "The most significant damage results from low-velocity impact, which may shatter the laminate internally but provide little or no visible surface damage." (References 4.3-4&5) During destructive tests (cross sectioning), delaminations were found at the site of the impact damage.

It should be noted that investigations by Williams (Reference 4.3-6) into the behavior of composites have found that transverse shear is also a failure mechanism. The transverse shear occurs in a few plies near a delamination "caused by wedges of failed material prying apart the plies."

4.3.3 Coupon/Panel IHM Program

4.3.3.1 Test Objectives

Verify and measure sensor technology performance to detect flaws, cracks, delaminations, impact damage, and other structural faults as required. Assess promising technologies as either an in-flight or on-ground tool. Identify deficiencies that, if improved, would substantially increase IHM's ability to perform. Much of the effort towards meeting this end will be met through actual sensor demonstration on the flaw induced coupons and panels.

A two-step demonstration process should be used to reach this objective starting with element size specimens (quantity TBD) and then scaling up to sub component size. Element size specimens provide small sections of hardware that can be mailed to vendors of NDI and sensor equipment for evaluations. Furthermore, NDI and sensor technology can then be optimized using the element size.

> **NOTE:** *The use of element size specimens is not part of the original statement of work. This additional requirement is suggested as a way to streamline the sensor selection and NDE/IHM integration process. Failure of NDE sensors late in the program schedule (component size specimens are available 6/95) to demonstrate capability will negatively affect the overall program schedule.*

Flaws (insert) representing delaminations will be placed between the plies during fabrication. Location and size will be determined by finite element analysis under Task 3, 4, and 5. Potential location considerations are: free edges, holes, ply drops, secondary bonds, and bolted joints. Insert material that prohibit the bonding of adjacent plies is a common method used to represent a delaminated condition. Insert material selection will be briefly examined at SSD so that the material used will not interfere with the NDE and sensor evaluation criteria. (rev. 7) Materials under consideration include; Teflon, graph foil (woven and solid), and mylar.

4.3.3.2 Test Articles

Element size: Articles will be fabricated under Task 3 (TA2) activities using the fabrication parameters established under their development efforts. The IHM element size articles must be separate from those used for other task 3 activities because pre induced flaws and sensors will be required. Pre induced flaws may include; impact damage or other failure modes imposed on the hardware prior to load testing. Sketches representing details of these articles will be included in this development plan as they become available.

Specimen	Availability	Comments
Intertank Stiffener (h)	2/95	Task 3 Test (h)
Intertank Skin/Stiffener(i)	2/95	Task 3 Test (i)
Thrust structure Ring Frame(s)	2/95	Task 4 Test (s)
Thrust Structure Engine Mount(t)	2/95	Task 4 Test (t)
Thrust Structure Shell Joint	2/95	Task 4 Test (u)
Wing /Aeroshell Skin/Stiffener	2/95	Task 5 Test (?)

Panel Size: Use planned (2) 18 x 36 inch panels -- one for intertank (Task 3) and one for wing structure (Task 5).

Specimen	Availability	Comments
Impact Panel (m)	6/95	Task 3 Test (m)
Vibroacoustic (n)	6/95	Task 3 Test (n)
Cyclic Strength (x)	TBD	TBD
Impact Panel	3/96	Task 5 Test (m)
Vibroacoustic	3/96	Task 5 Test (n)

4.3.3.3 Test Description

Piggyback NOC planned intertank and wing structure strain gauge NDI test and compare results. Run vibration tests at SSD for in-flight monitoring capability of NDE and sensor technologies.

4.3.3.4 Potential NDE/IHM Instrumentation

AE, UT, fiber optics, thermography, shearography -- Under each of the instruments is a brief description of their function and potential applicability to the element or sub component.

4.3.4 APPLICABLE DOCUMENTS

4.4 Full Scale Test Article (FSTA) Defect Standards

4.4.1 Using the Structural IHM System Definition Statement and the coupon/panel test data as a baseline, establish FSTA defect standards and requirements that need to be monitored and managed during the tests.

- Estimated completion date is 3 March 1995.
- Task effort will run from November 1994 through February 1995.
- Primary Responsibility: TBD

4.4.2 Approach

TBD

4.5. Full Scale Test Article (FSTA) IHM Tests

4.5.1. Integrate IHM requirements and sensors into the FSTA designs and implement the advanced sensor technology for use during the intertank structural integrity test at NASA-LaRC and thrust structure fatigue tests at NASA-MSFC.

- Estimated Completion Date 16 August 1996
- Task effort will run from April 1995 through July 1996.
- Primary Responsibility: TBD

4.5.2 Approach

4.5.3 FSTA IHM test Program

4.5.3.1 Test Objective

Develop and verify sensor technology to identify wing structure/TPS debonds and structural faults. Develop and verify sensor technology to detect intertank flaws, cracks and other structural faults.

4.5.3.2 Test Article Description

Wing structure with TPS and Intertank.

4.5.3.3 Test Description

Piggyback planned LaRC fatigue test on the Wing structure and TPS and planned structural integrity test on the intertank. Compare results.

4.5.3.4 Potential Instrumentation

AE, UT, fiber optics, thermography and shearography.

4.5.3.5 Test Location

NASA LaRC.

4.5.3.6 Applicable Documents

4.6. Integrated Health Management Integration

4.6.1 Requirement

Coordinate and provide IHM integration among all team member (NASA, SSD, NAAD, AFWL, and NOC) related IHM efforts. Related IHM efforts include conventional NDE to be performed by NAAD and NOC during the building block program and their tests dedicated to structural integrity. Effort also includes coordination with NASA-MSFC and LaRC during their on-site structural integrity tests.

- Estimated completion date is 27 September 1996.
- Task effort will run from June 1994 through September 1996.
- Primary Responsibility: TBD

4.6.2 Approach

TBD

4.7. IHM Report

4.7.1 Requirement

Provide IHM Program documentation, test results, lessons learned and recommendations for further efforts.

- Estimated completion date is 27 September 1996
- Task effort will run from July 1996 through September 1996
- Primary Responsibility: TBD

4.7.2 Approach

Quarterly and the final report will be the efforts of NASA/LaRC, ROC & SSD.

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