Scientific/Technical /Management Document

Response to Solicitation: NNH13ZEA001N-SSAT: B.2 System-Wide Safety Assurance Technologies (SSAT)

Title: Category-theoretic Approaches for the Analysis of Distributed Systems

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September 4, 2013

National Aeronautics and Space Administration
Langley Research Center
Hampton, VA 23681

Attention: Contracting Officer

Subject: Honeywell Response to NASA RESEARCH ANNOUNCEMENT: NNH13ZEA001N, entitled, Research Opportunities in Aeronautics -2013 (ROA-2013) Program entitled, "System-Wide Safety assurance Technology Project (SSAT1)", Appendix B.2 Subtopic # AFCS1.5, entitled, "Distributed Systems: Distributed Airspace Systems"

Reference: AMENDMENT No. 3 TO THE NASA RESEARCH ANNOUNCEMENT (NRA) ENTITLED "RESEARCH OPPORTUNITIES IN AERONAUTICS – 2013 (ROA-2013) NNH13ZEA001N, RELEASED December 18th, 2012

To Whom It May Concern:

Honeywell International Inc., Aerospace Defense and Space is pleased to provide NASA with the attached proposal, per the referenced NASA Research Announcement.

Included in our Technical proposal is a description of our Technical Approach, Management Plan, Implementation Plan, Statement of Work, including Program Schedule and Milestones, Deliverables, resumes of key personnel and other required material. Our detailed price proposal is provided as a separate attachment.

Our proposed prices by phase are as follows:
Phase 1: $307,938
Phase 2: $295,460
Phase 3: $297,032
Total proposed price for 3 Phase effort: $900,430

Quoted prices are based on upon tasks specified in the technical proposal and SOW, a Cost Plus Fixed Fee contract arrangement, a December 2013 start date, 12 month period of performance for each phase and mutually agreeable contract terms and conditions and appropriate agreement on protection of background Intellectual Property. This proposal will remain valid for 120 days.

Program Foreground Intellectual Property: It is Honeywell's intent that all deliverables under the contract be provided to NASA with unrestricted/unlimited rights.

Honeywell Intellectual Property: In accordance with the federal regulations for the Protection of Limited Rights Data and Restricted Computer Software, Honeywell has not identified technology as intellectual property that will be utilized in performance of this effort. However, Honeywell reserves the right to identify and update the listing to reflect background and proprietary

intellectual property that may be identified during the performance of this contract/award. Should this occur, the contractor will provide form, fit and function data in lieu thereof, as necessary, on all reporting required under award. Should any Honeywell proprietary data or limited rights data need to be disclosed or reported to the U.S. Government for NASA management or evaluation purposes, the protection period is indefinite and these items will contain restrictive markings.

A Petition for Advance Waiver of Patent Rights under NASA Research Announcement (NRA) NNH13ZEA001N is included in this proposal submittal.

Honeywell electronic representations and certifications are maintained at the System for Award Management (SAM) on-line application for representations and certifications. For the Certification Regarding Debarment, Suspension, and Other Responsibility Matters, Honeywell submits the following qualifying language for E.1.4:

> "On June 5, 2008, the U.S. Department of Justice filed a civil False Claims Act complaint against Honeywell, claiming that the company withheld information regarding alleged deficiencies in certain material sold for use in bullet-resistant vests, thereby causing Honeywell's customer, Armor Holdings, Inc., to make false claims for payment for bullet-resistant vests sold by Armor Holdings to government purchasers. Honeywell denies the government's allegations, believes they are without legal or factual merit, and is aggressively defending the litigation."

Honeywell requests that all proposal reviewers be employees of the U.S. Government.

This proposal is subject to final agreement by the parties, is not intended to be, and shall not constitute in any way a binding offer or legal agreement, or impose any legal obligation or duty on either Honeywell International Inc. or the recipient. This proposal is offered in its entirety.

Honeywell International Inc. is looking forward to supporting NASA on this program. For any technical questions, please contact Mr. Kevin Schweiker, at 763-954-6791 or kevin.schweiker@honeywell.com. Contractual matters may be directed to the undersigned.

Sincerely,

HONEYWELL INTERNATIONAL INC.

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1. Abstract

Establishing an assurance claim for a distributed safety critical system has proven extremely difficult. Developing and documenting the evidence needed to support a claim requires diverse models and abstractions of system properties to capture behaviors, understand error propagation, and evaluate the interactions with other systems and humans. The ability to scale and merge these diverse models and abstractions within a sound mathematical framework is the research objective of this proposal. A solution to this problem will reduce system development and certification times, while increasing safety. In addition, an overarching framework may lead to early identification of requirements gaps that have, in the past, plagued large distributed systems such as the FAA's Advanced Automation System and the U.S. Army's Future Combat Systems modernization program.

Honeywell has assembled a world-class team to develop a mathematical framework for the composition and scaling of models for the analysis of distributed flight critical systems. Category theory is one promising approach for this mathematical framework. We will initially focus on a subset of higher category theory known as operad theory and extend to alternate frameworks as necessary. We plan to evaluate the effects of disruptions and failures of NextGen communication channels on the safe separation of aircraft within the framework.

2. Table of Contents

2.1 Acronyms

ACARS	Aircraft Communications Addressing and Reporting System
ADS-B	Automatic Dependent Surveillance-Broadcast
AFCS	Assurance of Flight Critical Systems
ATC	Air Traffic Control
ATN	Aeronautical Telecommunication Network
CPDLC	Controller–Pilot Data Link Communications
CT	Category Theory
FAA	Federal Aviation Administration
FANS	Future Air Navigation System
FCS	Flight Critical Systems
FTPC	Fault Propagation and Transformation Calculus
HF	High Frequency (3-30MHz)
INTEROP	Interoperability Requirements
GBT	Ground-Based Transceiver
MASPS	Minimum Aviation System Performance Standards
MOPS	Minimum Operational Performance Standards
NAS	National Air Space
NASA	National Aeronautic and Space Administration
NextGen	Next Generation Air Transport System
NRA	NASA Research Announcement
ROA	Research Opportunities in Aeronautics
SD	Safety Diagram
SoS	System of Systems
SPR	Safety Performance Requirements
SSAT	System-Wide Safety Assurance Technologies Project
STAMP	System-Theoretic Process Analysis
TIS-B	Traffic Information Services Broadcast
UAT	Universal Access Transceiver
VDL-3	VHF Datalink Mode 3
VHF	Very High Frequency (30-300MHz)
VVFCS	Verification and Validation of Flight Critical Systems
WD	Wiring Diagram

3. Scientific / Technical / Management

3.1 Overview

The Honeywell Team is pleased to respond to the National Aeronautics and Space Administration (NASA) Research Announcement (NRA) entitled "Research Opportunities in Aeronautics – 2013 (ROA-2013), System-Wide Safety Assurance Technologies Project (SSAT1), Subtopic Number: AFCS 1.5: Distributed Systems: Distributed Airspace Systems.

Honeywell has teamed with the Massachusetts Institute of Technology (MIT) to develop and evaluate innovative techniques from the mathematical field of category theory (CT) as a framework to evaluate the overall performance of a System of Systems (SoS). Category theory is a branch of mathematics that can trace its origin to the 1940s. Over the years it has served as a formal framework for the organization of ideas. CT has provided new insights into the semantics of full first-order S4 modal logic, network analysis, and applied physics. Initially, the Honeywell Team will formulate the effects of disruptions and failures to NextGen communication channels on the safety invariant of safe separation of aircraft within a CT framework.

We will leverage both Honeywell's and MIT's domain knowledge and expertise to:

- Develop, within a CT framework, a view of the effects of individual and combined failures of NextGen communication technologies that support automated aircraft separation. This view will be constrained by relevant standards and requirements for safe separation and NextGen communication channels ;
- Use the CT framework to understand fault detection and evaluate mitigation strategies, especially for communication technologies;
- Establish within the CT framework a view of fault tolerance at the SoS level;
- Formulate various separation strategies on communication technologies that relate to safety within the CT framework; and
- Evaluate the ability of the CT framework to identify requirement gaps and determine emerging SoS behaviors, including adverse affects that may arise from the detection and mitigation of faults.

The Honeywell Team will work with NASA to ensure that this project supports the overall SSAT milestones of:

- Publish design/evaluation guide for safe distributed systems,
- Verify and document that design/evaluation guide provides safety assessment, and
- Advance safety assurance to enable deployment of NextGen Flight Critical Systems.

3.2 Honeywell

Honeywell is uniquely positioned with R&D and engineering expertise in flight safety products such as the Enhanced Ground Proximity Warning System (EGPWS) and the Traffic Alert and Collision Avoidance System (TCAS); weather products such as IntuVue™, the world's first 3-dimensional (3D) weather radar; flight management systems; flight information systems;

communication systems; surveillance systems; guidance, navigation, and control systems; flight operations; and displays. Honeywell's Communication, Navigation, and Surveillance (CNS) experts are responsible for the development of real-world NextGen flight deck systems, including all Honeywell TCAS and applications of Automatic Dependent Surveillance-Broadcast (ADS-B) offerings. Honeywell had a key role in developing Radio Technical Commission for Aeronautics (RTCA)/Design Objectives (DO)-300 Minimum Operational Performance Standards for TCAS II Hybrid Surveillance. Hybrid surveillance uses ADS-B squitters to track aircraft that are not near-collision threats as a means to reduce the use of active interrogations. Honeywell has also implemented ADS-B transmit and receive as an extension of its TCAS and transponder products and has worked with customer operators on ADS-B applications ranging from military formation flight to oceanic In-trail Procedures (ITP).

3.3 MIT

The Mathematics Department at MIT is a world leader in pure and applied mathematical research and education. In pure mathematics the department explores research directions in most of the major fields. In applied mathematics, the department explores important connections with other disciplines that may inspire interesting and useful mathematics, and where innovative mathematical reasoning may lead to new insights and applications. The applied math group at MIT focuses on biology, combinatorics, computer science, scientific computing, numerical analysis, and areas of physical applied mathematics. David Spivak, a Research Scientist in the Mathematics Department, and member of the Honeywell Team spans both pure and applies mathematics in the development an application of category theory.

For Dr. Spivak, it has become clear that English prose is not sufficiently robust to fully articulate an understanding of highly complex systems. For the past five years he has investigated the use of category theory to connect different schematic representations of knowledge so that data and insights can be translated from one such representation scheme to another. Dr. Spivak teaches a popular course in category theory that is open to all science majors at MIT and wrote the book *Category Theory for Scientists* to support the course. Dr. Spivak views category theory as a universal modeling language.

3.4 Objectives and Expected Significance

National authorities, such as the Federal Aviation Administration (FAA), have developed vertical, lateral, longitudinal separation standards to support safe navigation of aircraft in controlled airspace. These standards are designed to minimize ground and airborne hazards while limiting exposure to wake vortex turbulence. For the United States, these separation criteria are documented in the FAA administrative order JO 7100.65U, Air Traffic Control [1].

As part of the NextGen initiative, the FAA is introducing new technologies and services to increase the capacity and efficiency of the National Airspace (NAS) while simultaneously enhancing safety. Technologies such as Automatic Dependent Surveillance-Broadcast (ADS-B), Traffic Information Services Broadcast (TIS-B), and Controller–Pilot Data Link Communications (CPDLC) and their associated services provide the aircrew with a new level of situational awareness and coordination with Air Traffic Control. These technologies will allow the introduction of pilot-initiated and automated separation strategies.

ADS-B avionics broadcast frequent messages that contain the aircraft's position, velocity, identification, and other information. Additionally, these broadcasts can be received by ground-based transceivers (GBT) to provide air traffic surveillance services. In the United States (U.S.), two different data links have been adopted for use with ADS-B: 1090 MHz extended squitter (1090 ES) and the universal access transceiver (UAT). The 1090 ES link is intended for air transport aircraft and above, whereas the UAT link is intended for general aviation aircraft [2].

ADS-B provides surveillance service in areas without radar coverage and can enhance existing radar by providing greater target accuracy and higher update rate. Initial air-to-air applications of ADS-B are advisory use only, enhancing a pilot's visual acquisition of other nearby similarly equipped aircraft either airborne or on the airport surface.

TIS-B is the broadcast of traffic information to ADS-B-equipped aircraft from ADS-B GBTs. The source of this traffic information is derived from air traffic surveillance radars. TIS-B is intended to provide ADS-B equipped aircraft with a more complete traffic picture in situations where nearby aircraft are not equipped with ADS-B [3].

A standard communication channel between an air traffic controller and a pilot is voice radio, using either the HF or VHF bands. This channel is highly congested, subject to frequent errors, and not globally available. CPDLC provides a method by which air traffic controllers can communicate with pilots over a datalink system. CPDLC includes a set of clearance/information/request messages which correspond to voice phraseology employed by air traffic control procedures [4]. Today, there are two main implementations of CPDLC:

- The FANS-1/A system, used by both Boeing and Airbus, is primarily used in oceanic routes by wide-bodied long haul aircraft. FANS-1/A is an Aircraft Communications Addressing and Reporting System (ACARS) based service and, given its oceanic use, mainly uses satellite communications provided by the Inmarsat.
- The ICAO Doc 9705 compliant ATN/CPDLC system, which is operational at Eurocontrol's Maastricht Upper Airspace Control Centre.

A graphic representation of the NextGen communication systems that impact safe separation are illustrated in Figure 1.

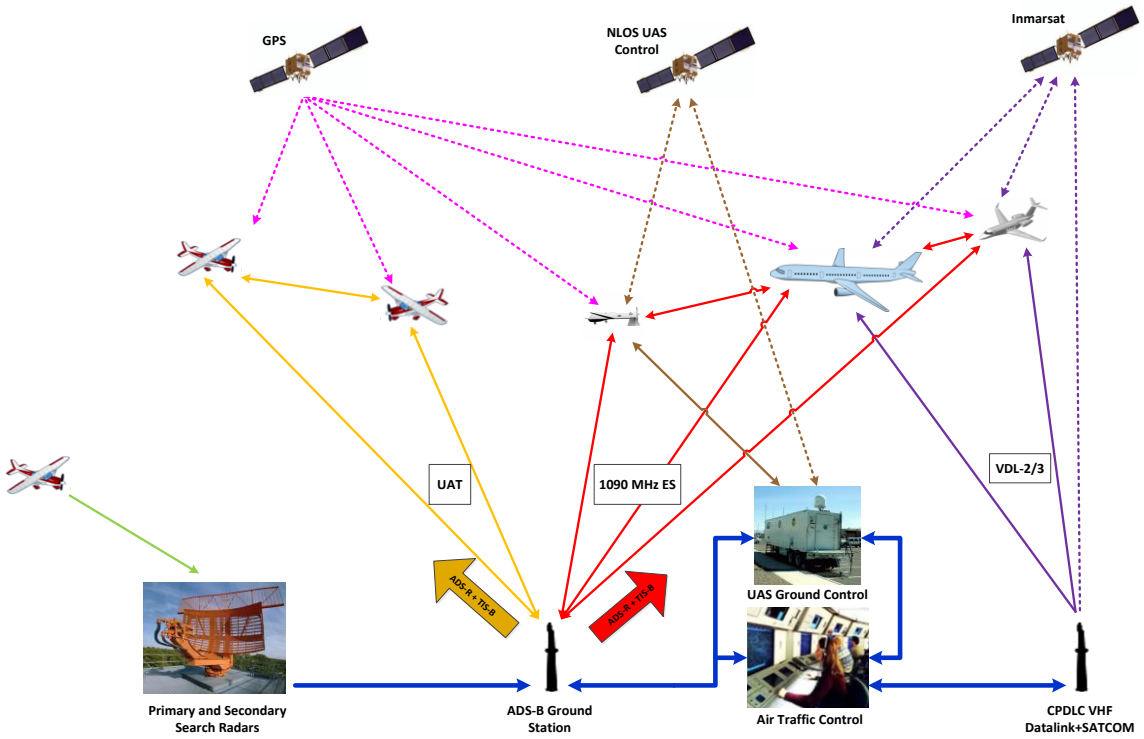


Figure 1: NextGen communication channels used to aid aircraft separation.

The expected significance of this work is the emergence of a mathematically sound approach, based on category theory, to provide evidence to support assurance claims and assertions related to distributed flight critical system. An example of such an assurance claim may be: The SoS consisting of: multiple aircraft equipped with operational ABS-B, TIS-B, TCAS-2, CPDLC hardware will not incur separation violations in excess of 10^{-5}/hr of operation.

3.5 Technical Approach and Methodology

In this project we will define an artifact called a safety diagram (SD). It will consist of an SoS that is composed of an interconnected network of systems. To claim that the SoS is "safe" will amount to claiming two things:

- That each system is "safe" in that respect; and
- That the interactions of these systems satisfy both high availability and high integrity.

As an analogy, to check that a human being is healthy one could check first that his circulatory, muscular-skeletal, nervous, and respiratory systems are each healthy, and second that the interactions between these systems is in working order.

This analysis lends itself to the mathematical theory of categories, or more specifically operads. These mathematical objects capture the notion of self-similarity, or to say it another way, the sense in which a large-scale object inherits traits from its constituents. An operad for safety claims would enunciate a sense in which local safety claims can be properly assembled into global safety claims.

The goal of this work is to enable the following workflow for safety certification. Suppose that a certifying authority is reviewing a system we have designed. We present the entire SoS using a safety diagram, which explains the constituent parts of the SoS as well as how they fit together. The authority, in order to question the safety of our SoS must choose to question either:

1 - the safety of a certain system, or

2 - the high availability and high integrity of the interaction between systems and humans.

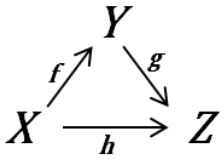
Let's assume that for our particular SoS we have established sufficient evidence and arguments such that #2 is satisfied. The certifying authority is now reviewing a system that has a lower-level safety diagram.

The mathematics of operads will assure us that this recursive protocol works as intended. It handles the integrity of such transitions between local claims and global claims. ***One question to be addressed during this study is whether category theory can anticipate any emergent behaviors from the system composition prior to them being observed in the SoS.***

3.5.1 Category Theory / Operads

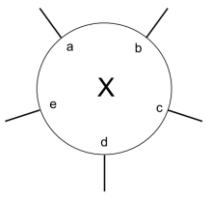
CT is an active area of research in both mathematics and theoretical computer science, and theoretical physics. Many researches consider it is a general mathematical theory of structures and of systems of structures [5]-[10].

As a non-rigorous introduction, a category consists of a collection of objects, a set of morphisms, identities and composition that conform to some laws, including an identity law and an associativity law. CT can trace its origins to the observation that mathematical structures can be represented with diagrams of arrows. For example, $f : X \to Y$ represents a function, where both X and Y are sets, and a rule $x \mapsto fx, x \in X, y \in Y$. A simple diagram of sets and functions is illustrated below.



The diagram is said to be commutative when $h = g \circ f$, where $g \circ f : X \to Z$. This category is known as **Set**. Many other categories have been developed and studied, including **Hask,** where the objects are types in the functional programming language of Haskell and the morphisms are functions between the types. See the references listed above for rigor.

An operad consists of a sequence $(P_n)_{n \in \mathrm{N}}$ of sets whose elements, X, can be thought of as *wiring diagram (WD)*, such as a singly-typed star, say X:={a,b,c,d,e}and drawn as follows:



Each element of X is called a wire of X. In an example from Spivak [9], illustrated on the left hand side of **Figure 2**, $\phi:(X_1,X_2,X_3)\to Y$, where $Y=\{a,b,c,d,e\}$ and the three domain objects are $X_1=\{r,s,t\}, X_2=\{u,v\}$, and $X_3=\{w,x,y,z\}$. The morphism ϕ has a set of "cables" $C=\{1,2,3,4,5\}$. In this example, $f_1(s)=f_3(w)=g(a)=1$, that is the wires s,w,a are "soldered" onto cable 1.

The composition of WDs are intuitively shown on the right hand side of Figure 2, here the composition $\phi'\circ(\phi_1,\phi_2,\phi_3)$, but are justified by CT concept of pushout. See [9] for more details.

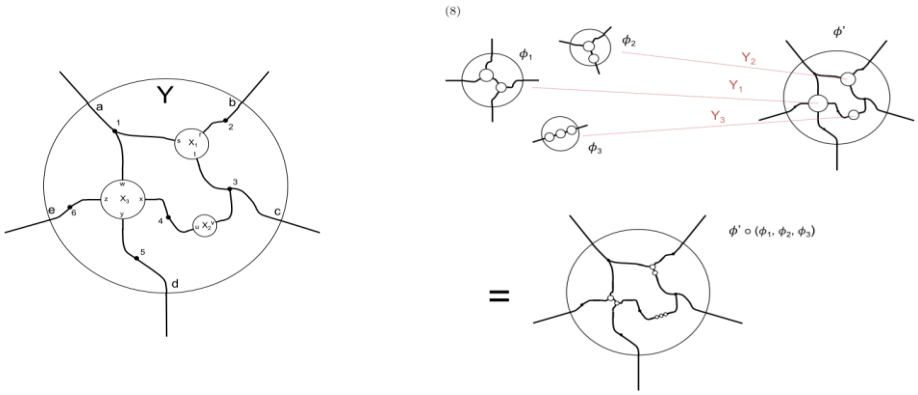


Figure 2: Composability of wiring diagrams (Spivak[9]).

To extend the concept of a WD to a safety diagram (SD) the first thing that needs to be defined are the objects. For the NextGen systems illustrated earlier in Figure 1, the initial objects we will consider are aircraft, ADS-B, TIS-B, TCAS-2, CPDLC and ATC. Each of these objects can be expanded into their own SDs that consist of system components, requirements and interface requirements. Each of the components can be recursively expanded into SDs of increasing detail. The requirements will initially be extracted from RTCA Safety Performance Requirements (SPR), Interoperability Requirements (INTEROP), Minimum Aviation System Performance Standards (MASPS), and Minimum Operational Performance Standards (MOPS) documents that provide standards for many of the systems [11]-[15].

In addition, there are structures that can serve as objects in our SDs. The initial structures of interest are those found in SAE ARP-4754, including: Function Hazard Assessments (FHA), Failure Mode and Effect (FMEA) and Fault Tree Analysis (FTA). Additional structures including formal ontologies developed from Formal Concept Analysis (FCA) [16], Leveson's System-Theoretic Process Analysis (STAMP) diagrams [17] and outputs from Wallace's Fault Propagation and Transformation Calculus (FTPC) [18] are also potential structures for inclusion in the collection of objects. Throughout this program we will work with our NASA sponsor to develop a consensus on what objects should be considered in the SD operad.

The morphism between system and subsystems can be interpreted as proof obligations that need to be executed to provide the person examining the SD of the validity of the morphism and the soundness of the evidence that is provided as support.

3.6 Perceived Impact of the Proposed Work

The proposed work will extend the theory and art for the analysis of SoS through the composition of systems. CT offers a rigorous approach to develop an infrastructure for this system composition. The capabilities can significantly reduce the occurrence of safety-related incidents caused by incorrect designs or optimistic fault assumptions (including Byzantine) in avionics systems and components, thus contributing to safer commercial aviation in increasingly challenging environments.

3.7 Relevance to NASA Programs

The proposed research draws upon many years of NASA research programs in support of assurance for advanced airspace and avionics. The development and evaluation of category-theoretic methods for the analysis of distributed systems will support three SSAT milestones:

- Publish design/evaluation guide for safe distributed systems;
- Verify and document that design/evaluation guide provides safety assessment; and
- Advance safety assurance to enable deployment of NextGen Flight Critical Systems (FCS).

3.8 General Plan of Work (Statement of Work)

3.8.1 Objectives

Our technical approach is to develop and integrate category-theoretic methods that assess how credible faults, disturbances, and degradations might adversely impact safety, focusing initially on distributed NextGen systems that provide data that supports automated aircraft separation.

The program will initially define safety concepts, such as, high integrity, high availability and the safe separation of aircraft, as mathematical objects. Similarly, safety assessment processes and methods found in ARP-4754 [19], ARP-4671 [20], STAMP/STA [17] and FPTC [18] will be cast as mathematical objects. Once a sufficient collection of safety objects exists the team will explore various category-theoretic methods to evaluate properties and behaviors of the safety objects. Including how the safety objects compose across system boundaries.

We refer throughout to *work packages (WP).* Section 3.8.2 describes the technical work packages in detail; for now we simply identify these to facilitate the discussion:

- WP DEF – work associated with defining safety concepts as mathematical objects
- WP STR – work associated with defining safety artifacts as mathematical objects
- WP CT – work associated with the development of various category-theoretic approaches for reasoning about safety concepts and artifacts
- WP EXA – work associated with the construction of compelling examples based on standards found in RTCA documents
- WP EVAL – work associated with evaluating the implications of the CT framework
- WP ADM – work associated with administrative tasks

Figure 3 depicts the relationship among the proposed work packages. We start with definitions and structures which flow into the development of category-theoretic methods. The

methods are combined with models derived from RTCA documents and real-world examples. The evaluation is feed back to drive the research in the out years of this program.

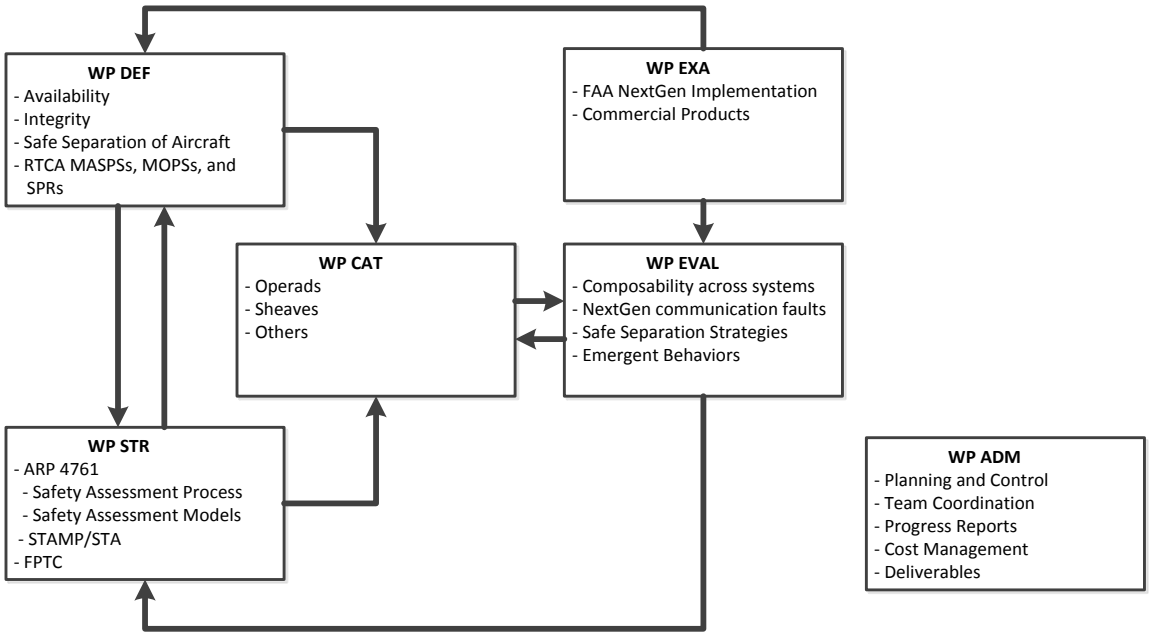


Figure 3: Flow between Work Packages

3.8.2 Year 1 Tasks

The six tasks that comprise the first year's effort of listed in a table format in the following subsections

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3.8.2.1 Task 1.1 WP DEF (Definitions)

Content	This work package defines common safety related terms and concepts, and casts them as mathematical objects. Once cast, these objects will flow to WP CAT I for inclusion in the category-theoretic methods.
Planned Accomplishments	(a) List of safety terms with initial definitions (b) Casting of the terms into mathematical objects.
Progress Metrics	(a) Object count. (b) Coverage of safety space.
Dependencies	None.
Honeywell Role	Develop list and textual definitions to be evaluated during the first year.
MIT Role	Transform safety terminology into mathematical objects.

3.8.2.2 Task 1.2 WP STR (Structures)

Content	This work package defines common safety assessment methods and casts them as mathematical objects. Once cast, these objects will flow to WP CAT I for inclusion in the category-theoretic methods.
Planned	(a) List of safety assessment methods with initial definitions (b) Casting

Accomplishments	of the methods into mathematical objects.
Progress Metrics	(a) Object count. (b) Coverage of safety space
Dependencies	None.
Honeywell Role	Develop list and definitions of assessment methods to be evaluated during the first year.
MIT Role	Transform safety assessment methodology into mathematical objects.

3.8.2.3 Task 1.3 WP CAT (Category Theoretic-Methods)

Content	This work package develops the category-theoretic structures that combine the objects above with a set of morphisms and composition approaches.
Planned Accomplishments	A report with: (a) Example category definition, (b) Examples, (c) Brief analysis.
Progress Metrics	Report generation.
Dependencies	Preliminary input from WP DEF I, WP STR I.
Honeywell Role	No role.
MIT Role	Lead for this work package.

3.8.2.4 Task 1.4 WP EXA (Examples)

Content	This work package develops examples derived from multiple RTCA documents and experience with field hardware performing a subset of the envisioned NextGen functionality.
Planned Accomplishments	(a) Notional or real-world example consisting of NextGen communication nodes and safe separation as the safety invariant.
Progress Metrics	(a) Example count.
Dependencies	None.
Honeywell Role	Lead for this work package.
MIT Role	Monitor.

3.8.2.5 Task 1.5 WP EVAL (Evaluation)

Content	This work package extends the work of WP CT I by exploring the implications of category-theoretic techniques with notional or real-world NextGen systems. Emphasis will be on the affects of communication disruptions on safety invariants, such as safe separation.
Planned Accomplishments	(a) Evaluation of a category-theoretic method as a framework for modeling effects of disruptions across distributed systems. (b) Report on the example and results from the evaluated Category-theoretic method.
Progress Metrics	(a) Publication of a NASA Technical Report describing the evaluation
Dependencies	WP CT I, WP EXA I.
Honeywell Role	Monitor.
MIT Role	Lead for this task.

3.8.2.6 Task 1.6 WP ADM (Administration)

Content	This work package captures all of the administrative duties for the phase.
Planned Accomplishments	The administrative tasks include at least the following activities: • Project planning and control

	• Team coordination • Customer interaction and feedback incorporation • Progress reporting • Cost management • Deliveries
Deliverables	1 One kickoff meeting and presentation (travel or web conf.) 2 Three quarterly meetings, reports, and presentations describing progress on work packages, deliverables, and milestones (web conferences) 3 Eight monthly progress report emails 4 One interim/final meeting, report, and presentation describing progress on work packages, deliverables, and milestones, and describing plans for the next phase or open work (travel) 5 In Phase III, one journal paper describing accomplishments and plan
Progress Metrics	Deliverables provided.
Dependencies	Statement of work and contract.
Honeywell Role	Support report writing and meetings, by deliverable above: 1 1 trip @ 16 hours (Phase 1); 2 meetings @ 4 hours (Phase II, III); report contributions 4 hours (each phase) 2 3 meetings @ 3 hours (each phase); report contributions 4 hours (each phase) 3 8 reports @ 1 hour (each phase) 4 1 trip @ 16 hours (each phase); report contributions 4 hours (each phase) 5 Journal paper contributions @ 40 hours (Phase III)

3.8.3 Year 2 Tasks

The second year's tasks are notionally similar to the first year's tasks, extending the safety definitions and structures, further development of the category-theoretic methods, and evaluation of additional examples. Specific tasks will be modified, with the consent of NASA, based upon the results of the first year's effort.

3.8.4 Year 3 Tasks

The third year's tasks are notionally similar to the first year's tasks, extending the safety definitions and structures, further development of the category-theoretic methods, and evaluation of additional examples. Specific tasks will be modified, with the consent of NASA, based upon the results of the first and second year's effort.

3.8.5 Schedule, Milestones and Deliverables

A compressed version of the program schedule, milestones and deliverables is presented below in Figure 4 assuming a start date of December 2, 2013.

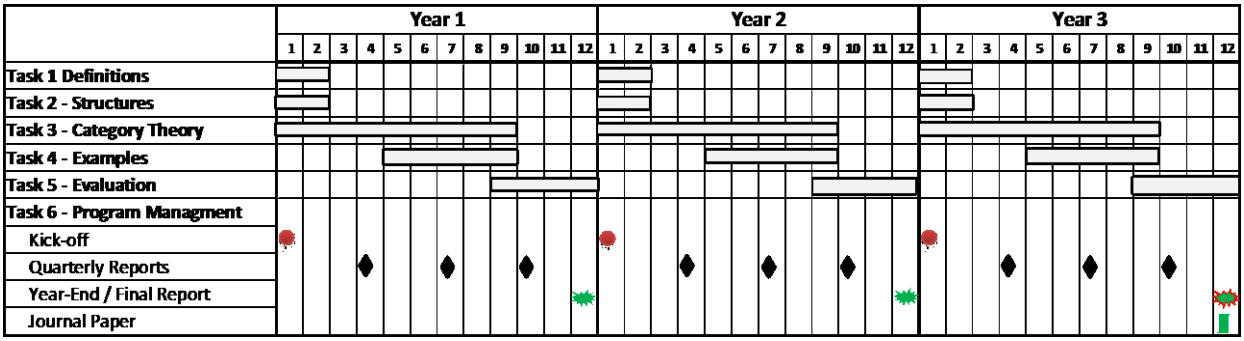

Figure 4: Program Schedule.

3.9 Data Sharing Plan

For over 50 years, Honeywell has partnered with Government agencies such as NASA, DARPA, and AFRL to develop advanced technology that will enhance our country's safety and security and maintain US technology leadership. Honeywell technology and products can be found in a broad range of today's commercial air transport, space and military applications. As a long-time government partner, Honeywell places strong emphasis on sharing non-proprietary information with the government and commercial companies. Honeywell encourages its scientists to publish non-proprietary research results and to participate in government and industry sponsored forums, workshops, and conferences. We will work closely with NASA to make available the non-proprietary data and information generated under the program by the Honeywell team.

4. References and Citations

[1] FAA, Administration Order JO 7110.65U, Air Traffic Control, and the Briefing Guide, 2013.
[2] ADS-B, http://www.faa.gov/nextgen/implementation/programs/adsb/, accessed 8/2/2013
[3] TIS-B, http://www.faa.gov/air_traffic/publications/atpubs/aim/aim0405.html, accessed 8/2/2013.
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[5] Mac Lane, Saunders. Categories for the working mathematician. Vol. 5. Springer Verlag, 1998.
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5. Biographic Sketches

5.1 The Honeywell Team

Honeywell International Inc, as the program prime contractor, along with its subcontractor the Massachusetts Institute of Technology offer NASA an unparalleled combination of multi-disciplinary expertise, experience, tools, and methods to satisfy the objectives of AFSC 1.5: Distributed Systems: Distributed Airspace Systems.

Honeywell International is a U.S. $34-billion diversified technology and manufacturing leader, employing over 110,000 people worldwide. It serves customers with aerospace products and services; control technologies for buildings, homes and industry; automotive products; power generation systems; specialty chemicals; fibers; plastics; and electronic and advanced materials.

Honeywell Aerospace is a leading global provider of integrated avionics, engines, systems, and service solutions for aircraft manufacturers, airlines, business and general aviation, military, space, and airport operations. We enhance customer value by making flight safer, more reliable, and more cost-effective through sophisticated avionics, flight safety products and systems, propulsion engines, auxiliary power units, and wheels and brakes and our strong aftermarket service and support. We are committed to redefining customer-supplier relationships across a broad array of core competencies, including power, guidance, navigation, safety, communication, and services—all through a spirit of partnership.

Our aerospace products can be found on virtually every type of aircraft in use, in nearly every region of the world. In the air and on the ground, Honeywell systems and components reflect cutting-edge technology incorporated from our product development efforts. These efforts contribute to Honeywell's unequaled variety of products and services, leading to greater customer satisfaction.

Honeywell's Advanced Technology (AT) organization serves as the central aerospace research and development (R&D) center. It supports advanced technology and related product development activities for all of Honeywell's Aeronautics, Defense and Space businesses. This AT organization performs roughly $150M of annual R&D activities. Approximately 50% of annual R&D expenditures stem from government agencies and collaborations with other primes. The organization employs close to 400 research scientists who hold advanced degrees in a broad range of disciplines.

The mission of MIT is to advance knowledge and educate students in science, technology, and other areas of scholarship that will best serve the nation and the world in the twenty-first century. MIT seeks to develop each member of its community with the ability and passion to work wisely, creatively, and effectively for the betterment of humankind. The Mathematics Department at MIT is a world leader in pure and applied mathematical research and education. In pure mathematics the department explores research directions in most of the major fields. In applied mathematics, the department explores important connections with other disciplines that may inspire interesting and useful mathematics, and where innovative mathematical reasoning may lead to new insights and applications. The applied math group at MIT focuses on biology, combinatorics, computer science, scientific computing, numerical analysis, and areas of physical applied mathematics.

5.2 Kevin Schweiker, Co-PI, PM, Honeywell International

Education

Ph.D. Mathematics, University of South Florida, Tampa, 1993.

Advisor: Joseph Liang

Dissertation: Fractal Measure Theory

B.A. Astronomy and Mathematics, University of South Florida, 1982.

Dr. Schweiker is a Staff Scientist in the Honeywell Advanced Technology Crew Interface and Platform Systems Group. He is currently the Program Manager for the Verification and Validation of Flight Critical Systems Technical Area 2. In addition to administrative tasks, he also provided significant technical input for this program in the areas of agreement and integration services, redundancy management, and applications of CT to analysis of systems of systems. Prior to joining Honeywell, Dr. Schweiker worked in the defense industry developing and deploying weapon systems and mission critical computers for a variety of ground-based and airborne vehicles.

Selected Recent Publications

[1] Driscoll, Kevin R., Brendan Hall, and Kevin Schweiker. "Application Agreement and Integration Services." NASA/CR–2013-217963 (2013).

[2] Hall, Brendan, Kevin Driscoll, Kevin Schweiker, and Bruno Dutertre. "Investigating Actuation Force Fight with Asynchronous and Synchronous Redundancy Management Techniques." NASA/CR-2013-217984 (2013).

[3] Hall, Brendan, Kevin Driscoll, and Kevin Schweiker. "Verification and validation of flight critical systems (VVFCS)." In *Digital Avionics Systems Conference (DASC), 2012 IEEE/AIAA 31st*, pp. 1-18. IEEE, 2012.
[4] Schweiker, Kevin, and Brendan Hall. "Considerations in the presentation of evidence." In *Digital Avionics Systems Conference (DASC), 2012 IEEE/AIAA 31st*, pp. 9E5-1. IEEE, 2012.
[5] Pedersen, John F., Edward B. Saff, and Kevin S. Schweiker. "Wavelets for training a neural network to recognize objects." In *Optical Engineering and Photonics in Aerospace Sensing*, pp. 244-254. International Society for Optics and Photonics, 1993.

5.3 David Spivak, Co-PI, MIT

Education

Ph.D. Mathematics, University of California, Berkeley, 2007.

Advisor: Peter Teichner.

Dissertation: Quasi-smooth derived manifolds.

B.S. Mathematics, University of Maryland, College Park, 2000.

Experience

Upon receiving his Ph.D. Dr. Spivak served for three years as the Paul Olum Visiting Assistant Professor at the Department of Mathematics. In 2010 Dr. Spivak accepted a position at MIT and now serves as a Research Scientist in the MIT's Department of Mathematics. During this time he has served as the Principal Investigator on several Office of Naval Research grants focusing on databases, networks, and categorical informatics.

Selected Publications

Journal Articles

[1] Spivak, D.I.. (2013) "Database queries and constraints via lifting problems." To appear in Mathematical structures in computer science. ePrint available: http://arxiv.org/abs/1202.2591

[2] Spivak, D.I. (2012) "Functorial Data Migration". Information and communication. Vol 217, pp. 31 – 51.ePrint available: http://arxiv.org/abs/1009.1166

[3] Giesa, T.; Spivak, D.I.; Buehler, M.J. (2012) "Category theory based solution for the building block re-placement problem in materials design". Advanced Engineering Materials. DOI: 10.1002/adem.201200109

[4] Spivak, D.I.; Kent, R.E. (2012) "Ologs: a categorical framework for knowledge representation". PLoS ONE 7(1): e24274. doi:10.1371/journal.pone.0024274.

[5] Wong, J.Y.; McDonald, J.; Taylor-Pinney, M.; Spivak, D.I.; Kaplan, D.L.; Buehler, M.J. (2012) "Materialsby design: Merging proteins and music". Nano Today 7, issue 6, pp. 488 – 495.

[6] Giesa, T.; Spivak, D.I.; Buehler M.J. (2011) "Reoccurring patterns in hierarchical protein materials and music: The power of analogies". BioNanoScience 1 no. 4, pp. 153-161.

[7] Spivak, D.I.; Giesa, T.; Wood, E.; Buehler,M.J. (2011) “Category Theoretic Analysis of Hierarchical Protein Materials and Social Networks." PLoS ONE 6(9): e23911. doi:10.1371/journal.pone.0023911

[8] Dugger, D.; Spivak, D.I. (2011) “Rigidification of quasi-categories." Algebraic and Geometric Topology 11 pp. 225-261.

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[10] Spivak,D.I. (2010) “Derived Smooth Manifolds." Duke Mathematical Journal 153, no. 1, pp. 55-128.

[11] Batra, P.; Dobrescu, B.A.; Spivak, D.I. (2006) “Anomaly-free sets of fermions." Journal of Mathematical Physics, 47, 082301.

Preprints

[12] Spivak, D.I. (2013) “The operad of wiring diagrams: Formalizing a graphical language for databases, recursion, and plug-and-play circuits." Available online: tp://arxiv.org/abs/1305.0297

[13] Spivak, D.I. (2013) Category theory for scientists. 261 pages. Available online: http://arxiv.org/abs/1302.6946

[14] Spivak, D.I.; Wisnesky, R. (2012) “On the relational foundations of functorial data migration." Submitted to PODS. ePrint available: http://arxiv.org/abs/1212.5303.

[15] Spivak, D.I. (2012) “Kleisli database instances". ePrint available: http://arxiv.org/abs/1209.1011.

[16] Spivak, D.I.. (2010) “Table manipulation in simplicial databases". ePrint available: http://arxiv.org/abs/1003.2682.

[17] Spivak, D.I. (2009) “Simplicial databases." ePrint available: http://arxiv.org/abs/0904.2012.

5.4 Facilities and Equipment

Honeywell and MIT have all the facilities and equipment necessary to carry out the work identified in this proposal.

6. Current and Pending Support

Current and Pending Support for Key Honeywell and MIT Personnel Supporting the Honeywell Lead AFCS1.5 Distributed Systems: Distributed Airspace Systems Program

Project Title	Principal Investigator	Sponsoring Agency	Performance Period	Total Budget @Price	Commitment from 12/01/13
Kevin Schweiker Honeywell					
CertWareABSA	Mathew Barry (Kestrel)	NASA/Kestrel	06/01/2013-03/07/2014	$137K	2 Months PoP
David Spivak MIT					
Categorical Informatics	David Spivak	Navy-ONR	09/01/2013-08/31/2017	$135K	Y1: 3.7 months Y2: 8.9 months
Categorical approach to agent interaction	David Spivak	Air Force	06/01/2013-05/31/2018	$920K	9 month PoP

7. Statements of Commitment and Letters of Support

7.1 Letter of Commitment – Kevin Schweiker

Honeywell

Honeywell Aerospace
Honeywell
1985 Douglas Drive North
Golden Valley, MN 55422

September 5, 2013

Pavan Allalaghatta
Honeywell International Inc.
1985 Douglas Drive

Subject: Acknowledgement

Golden Valley, MN 55422

I, Kevin Schweiker, acknowledge that I am identified by name as the Principal Investigator (PI) to the investigation, entitled, "Distributed Systems: Distributed Airspace Systems" that is being submitted by under my name from Honeywell International Inc., in response to the NASA Research Announcement NNH13ZEA001N, Appendix B.2, Subtopic AFCS 1.5, entitled, "System-Wide Safety Assurance Technologies Program" and that I intend to carry out all responsibilities identified for me in this proposal. I understand that the extent and justification of my participation as stated in this proposal will be considered during peer review in determining in part the merits of this proposal.

Sincerely,

Kevin Schweiker, Principal Research Scientist

7.2 Letter of Commitment – David Spivak

Ian Cariolo
Contract & Grant Administrator

Massachusetts Institute of Technology
77 Massachusetts Avenue, Building NE18-901
Cambridge, Massachusetts 02139-4307

Office of Sponsored Programs

Phone 617.253.7260
Fax 617.253.4734
Email icariolo@mit.edu
http://web.mit.edu/osp/

August 27, 2013

Kevin Schweiker
Integrated Supply Chain
Honeywell International Inc.
Aerospace
13350 US Hwy 19 N.
Clearwater, FL 33764

Re: MIT Proposal under NASA Prime NNH13ZEA001N

Mr. Schweiker:

The Massachusetts Institute of Technology (MIT) submits herewith a proposal entitled, "Category-theoretic Approaches for the Analysis of Distributed Systems" for inclusion with your proposal to NASA's solicitation NNH13ZEA001N. The research will be performed under the direction of Dr. David Spivak as Principal Investigator in MIT's Department of Mathematics.

We are requesting funding in the amount of $300,000 in total estimated costs for the period of December 1, 2013 through November 30, 2016.

Should this proposal result in an award under a prime contract from NASA, Massachusetts Institute of Technology is prepared to accept and/or negotiate a grant in good faith with Honeywell, with terms and conditions appropriate for research conducted by an educational institution. This proposal represents unclassified contracted fundamental research exempt from prepublication controls and review requirement. In addition we wish to note MIT policy prohibits the acceptance of awards that include provisions that restrict our ability to disseminate research results or place limitations on the use of foreign nationals working on the research. MIT is committed to adhering to all applicable export control laws and regulations that pertain to the performance and dissemination of our research and to the export of tangible items such as equipment, components or materials. MIT will not, however, agree to accept research, agreements or information that might result in the imposition of export control requirements in conflict with our policies on open research and free interchange of information. MIT conducts only fundamental research as defined by the export control regulations - namely, openly-conducted basic and applied research in science and engineering that is not subject to access, dissemination, or participation restrictions. MIT shall have the right to terminate the research project if the disclosure of export controlled information, under license or otherwise, would destroy MIT's ability to invoke the fundamental research exclusion with regard to the conduct or reporting of its research.

Upon award of its Prime Contract from NASA, Honeywell will provide to MIT any Government flow down Clauses that may apply to the award received from NASA. At that time MIT will review these government clauses to confirm whether they are acceptable to MIT.

Please direct any questions relating to technical aspects of the proposal to the Principal Investigator. Questions of an administrative nature may be directed to the undersigned at 617-253-7260 or icariolo@mit.edu .

Sincerely,

Ian Cariolo
Grants/Contract Administrator

8. Budget Justification

8.1 Budget Narrative

Section 3.8 describes six tasks per year including: Administration, Definitions, Structure, Category-Theoretic Methods, Examples, and Evaluation. In addition, there is one task per year for MIT. This results in a total of twenty-one (21) justifications which are provided below.

8.2 Budget Details

Honeywell Labs
Cost Basis of Estimate (BOE)

	Program Name: AFCS1.5 Dist Air Space SYS	
Task/WBS Number: 1.1	**Prepared by:** Kevin Schweiker	**Date Prepared:** 8/13/2013
Task Title: Administration (Year 1)	**Approved by:** Pavan A	**Revision:**
		Period of Performance: 12/2/13 11/28/14
SOW Ref:		

Task Definition:

This task captures all the Program management tasks, meetings and presentations to NASA for the first year of the program.

Basis of Estimate / Thought Process and Assumptions:

Program Management - Best judgement estimate 4 hrs per month to track internal spending and maintain Honeywell required documentation (risk registar, Earned Value managment, MOR Quad Charts. This estimate is an estimate based. Financial Analyst of 12 hr per month based on VVFCS TA 2.
Subconracts - Includes labor for face to face meeting with MIT Subcontractor. Assue one meeeting in February for two days
Set-up svn, collaborating environment, 2 hours
Year 1 Kick-off Presentation, LaRC - estimate of 8 hrs prep, conduct 1 day review at LaRC
Year 1, Q1 Report, Webcast - prep of 3 hours, conduct 1 hour webcast
Year 1, Q2 Report, Webcast - prep of 3 hours cconduct 1 hour webcast
Year 1, Q3 Report, Webcast - prep of 3 hrs, conduct 1 hr webcast
Year 1 Interim Report, Presentation LaRC, prep of 8 hrs, conduct 1 day review at LaRC

Basis of Estimate / Actual History:

Program:		**Tally Number:**
Yes:		**Actual Hours:**
No:	X	**Period of Performance:**

Extrapolation Methodology / Assumptions:

This estimate is based on the originator's best judgment, general knowledge and experience from performing similar similar tasks on other programs.

Estimate (hours and material dollars):

	Hours or Dollars
ACS ENG003 (Prof Engr A)	
ACS ENG004 (Prof Engr B)	
ACS BUS003 (Ops Finance)	
ACS TEC003 (Technician)	
ACS STD003 (Student)	
Aero ENG001 (Prof Engr A)	124
Aero ENG002 (Prof Engr B)	
Aero BUS001 (PP&C)	152
Aero TEC001 (Technician)	
Aero STD001 (Student)	

Travel	2,664	Cost with G&A Only	
HLAB Purch w ACQ and G&A		Material Pass thru	
Purch Services ACQ and G&A		Matl w HW Part No Full Burden	
Interdivisional No Acq		Interdivisional w/Acq	

Honeywell Labs
Cost Basis of Estimate (BOE)

	Program Name: AFCS1.5 Dist Air Space SYS	
Task/WBS Number: 1.2	**Prepared by:** Kevin Schweiker	**Date Prepared:** 8/13/2013
Task Title: Definition (Year 1)	**Approved by:** Pavan A	**Revision:**
		Period of Performance: 12/11/13 1/28/14
SOW Ref:		

Task Definition:

Definition of terms and concepts. The output of this task flows to Task 4.

Basis of Estimate / Thought Process and Assumptions:

Safety Terms and Concepts
Mathematical Casting of Terms and Concepts

Basis of Estimate / Actual History:

Program:

Yes: [ ]
No: [X]

Tally Number:
Actual Hours:
Period of Performance:

Extrapolation Methodology / Assumptions:

This estimate is based on the originator's best judgment, general knowledge and experience from performing similar tasks on other programs – estimated to entail approximately 1 full week hours of an A Engineer with a 2 day review by a second A Engineer. Suncontractor also reviews definition.

Estimate (hours and material dollars):

	Hours or Dollars
ACS ENG003 (Prof Engr A)	
ACS ENG004 (Prof Engr B)	
ACS BUS003 (Ops Finance)	
ACS TEC003 (Technician)	
ACS STD003 (Student)	
Aero ENG001 (Prof Engr A)	56
Aero ENG002 (Prof Engr B)	
Aero BUS001 (PP&C)	
Aero TEC001 (Technician)	
Aero STD001 (Student)	

Travel	Cost with G&A Only
HLAB Purch w ACQ and G&A	Material Pass thru
Purch Services ACQ and G&A	Matl w HW Part No Full Burden
Interdivisional No Acq	Interdivisional w/Acq

Honeywell Labs
Cost Basis of Estimate (BOE)

	Program Name: AFCS1.5 Dist Air Space SYS	
Task/WBS Number: 1.3	**Prepared by:** Kevin Schweiker	**Date Prepared:** 8/13/2013
Task Title: Structures (Year 1)	**Approved by:** Pavan A	**Revision:**
		Period of Performance: 12/11/13 1/28/14
SOW Ref:		

Task Definition:

Define structures, such as GSN-based graphics that need to be incorporated into the category. This output of this task flows to Task 4.

Basis of Estimate / Thought Process and Assumptions:

Safety Assessment methods
Mathematical Casting of Methods

Basis of Estimate / Actual History:

Program:

Yes: [ ]
No: [X]

Tally Number:
Actual Hours:
Period of Performance:

Extrapolation Methodology / Assumptions:

This estimate is based on the originator's best judgment, general knowledge and experience from performing similar tasks on other programs – estimated to entail approximately 1 full week hours of an A Engineer with a 2 day review by a second A Enginee Subcontractor also reviews the structure definitions.

Estimate (hours and material dollars):

	Hours or Dollars
ACS ENG003 (Prof Engr A)	
ACS ENG004 (Prof Engr B)	
ACS BUS003 (Ops Finance)	
ACS TEC003 (Technician)	
ACS STD003 (Student)	
Aero ENG001 (Prof Engr A)	56
Aero ENG002 (Prof Engr B)	
Aero BUS001 (PP&C)	
Aero TEC001 (Technician)	
Aero STD001 (Student)	

Travel	Cost with G&A Only
HLAB Purch w ACQ and G&A	Material Pass thru
Purch Services ACQ and G&A	Matl w HW Part No Full Burden
Interdivisional No Acq	Interdivisional w/Acq

Honeywell Labs
Cost Basis of Estimate (BOE)

	Program Name: AFCS1.5 Dist Air Space SYS	
Task/WBS Number: 1.4	**Prepared by:** Kevin Schweiker	**Date Prepared:** 8/13/2013
Task Title: Category Theory (Year 1)	**Approved by:** Pavan A	**Revision:**
		Period of Performance: 12/11/13 8/19/14
SOW Ref:		

Task Definition:

This task develops the category-theoretic methods used to evaluate SoS. This task has input from Tasks 2 and 3 and provides output to Task 6.

Basis of Estimate / Thought Process and Assumptions:

Definition of Category
Examples within Category
Brief Analysis of Category

Basis of Estimate / Actual History:

Program:		**Tally Number:**
Yes:		**Actual Hours:**
No:	X	**Period of Performance:**

Extrapolation Methodology / Assumptions:

This is the main task of Year 1 effort, estimate is based on the originator's best judgment.
Subcontractor develops the category theory structure. Level A review and oversight estimated at 3.5 weeks (18 days).

Estimate (hours and material dollars):

	Hours or Dollars
ACS ENG003 (Prof Engr A)	
ACS ENG004 (Prof Engr B)	
ACS BUS003 (Ops Finance)	
ACS TEC003 (Technician)	
ACS STD003 (Student)	
Aero ENG001 (Prof Engr A)	144
Aero ENG002 (Prof Engr B)	
Aero BUS001 (PP&C)	
Aero TEC001 (Technician)	
Aero STD001 (Student)	

Travel	Cost with G&A Only
HLAB Purch w ACQ and G&A	Material Pass thru
Purch Services ACQ and G&A	Matl w HW Part No Full Burden
Interdivisional No Acq	Interdivisional w/Acq

Honeywell Labs
Cost Basis of Estimate (BOE)

	Program Name: AFCS1.5 Dist Air Space SYS	
Task/WBS Number: 1.5	**Prepared by:** Kevin Schweiker	**Date Prepared:** 8/13/2013
Task Title: Examples/Case Studies (Year 1)	**Approved by:** Pavan A	**Revision:**
		Period of Performance: 5/28/14 7/29/14
SOW Ref:		

Task Definition:

Develops first years example for analysis by the categoric-methods developed in Task 4. This serves as input for Task 6.

Basis of Estimate / Thought Process and Assumptions:

NextGen Example

Basis of Estimate / Actual History:

Program:		**Tally Number:**
Yes:		**Actual Hours:**
No:	X	**Period of Performance:**

Extrapolation Methodology / Assumptions:

This estimate is based on the originator's best judgment, general knowledge and experience from performing similar tasks on other programs – estimated to entail 11 days of an A Engineer effort.

The subcontractor will also provide input into the example.

Estimate (hours and material dollars):

	Hours or Dollars
ACS ENG003 (Prof Engr A)	
ACS ENG004 (Prof Engr B)	
ACS BUS003 (Ops Finance)	
ACS TEC003 (Technician)	
ACS STD003 (Student)	
Aero ENG001 (Prof Engr A)	72
Aero ENG002 (Prof Engr B)	
Aero BUS001 (PP&C)	
Aero TEC001 (Technician)	
Aero STD001 (Student)	

Travel	Cost with G&A Only
HLAB Purch w ACQ and G&A	Material Pass thru
Purch Services ACQ and G&A	Matl w HW Part No Full Burden
Interdivisional No Acq	Interdivisional w/Acq

Honeywell Labs
Cost Basis of Estimate (BOE)

	Program Name: AFCS1.5 Dist Air Space SYS	
Task/WBS Number: 1.6	**Prepared by:** Kevin Schweiker	**Date Prepared:** 8/13/2013
Task Title: Evaluation (Year 1)	**Approved by:** Pavan A	**Revision:**
		Period of Performance: 8/20/14 11/20/14
SOW Ref:		

Task Definition:

Evaluate impact of te category-theoretic methods in analyzing the NextGen example developed in Task5. Tasks 4 and 5 inputs. The output will be incorporated in the year-end report.

Basis of Estimate / Thought Process and Assumptions:

Evaluation of comms disruptions on Safe Separation Technical Report

Basis of Estimate / Actual History:

Program:

Yes: [ ]

No: [X]

Tally Number:
Actual Hours:
Period of Performance:

Extrapolation Methodology / Assumptions:

This estimate is based on the originator's best judgment, general knowledge and experience from performing similar tasks on other programs – estimated to entail 12 days of an A Engineer effort.

The subcontractor will also provide input into the example.

Estimate (hours and material dollars):

	Hours or Dollars
ACS ENG003 (Prof Engr A)	
ACS ENG004 (Prof Engr B)	
ACS BUS003 (Ops Finance)	
ACS TEC003 (Technician)	
ACS STD003 (Student)	
Aero ENG001 (Prof Engr A)	96
Aero ENG002 (Prof Engr B)	
Aero BUS001 (PP&C)	
Aero TEC001 (Technician)	
Aero STD001 (Student)	

Travel	Cost with G&A Only
HLAB Purch w ACQ and G&A	Material Pass thru
Purch Services ACQ and G&A	Matl w HW Part No Full Burden
Interdivisional No Acq	Interdivisional w/Acq

Honeywell Labs
Cost Basis of Estimate (BOE)

	Program Name: AFCS1.5 Dist Air Space SYS	
Task/WBS Number: 2.1	**Prepared by:** Kevin Schweiker	**Date Prepared:** 8/13/2013
Task Title: Administration (Year 2)	**Approved by:** Pavan A	**Revision:**
		Period of Performance: 12/1/14 11/30/15
SOW Ref:		

Task Definition:

This task captures all the Program management tasks, meetings and presentations to NASA for the second year of the program.

Basis of Estimate / Thought Process and Assumptions:

Program Management - Best judgement estimate 4 hrs per month to track internal spending and maintain Honeywell required documentation (risk registar, Earned Value managment, MOR Quad Charts. This estimate is an estimate based. Financial Analyst of 12 hr per month based on VVFCS TA 2.
Subconracts - Includes labor for face to face meeting with MIT Subcontractor. Assue one meeeting in February for two days
Set-up svn, collaborating environment, 2 hours
Year 2 Kick-off Presentation, LaRC - estimate of 8 hrs prep, conduct 1 day review at LaRC
Year 2, Q1 Report, Webcast - prep of 3 hours, conduct 1 hour webcast
Year 2, Q2 Report, Webcast - prep of 3 hours cconduct 1 hour webcast
Year 2, Q3 Report, Webcast - prep of 3 hrs, conduct 1 hr webcast
Year 2 Interim Report, Presentation LaRC, prep of 8 hrs, conduct 1 day review at LaRC

Basis of Estimate / Actual History:

Program:		**Tally Number:**
Yes:		**Actual Hours:**
No:	X	**Period of Performance:**

Extrapolation Methodology / Assumptions:

This estimate is based on the originator's best judgment, general knowledge and experience from performing similar similar tasks on other programs.

Estimate (hours and material dollars):

	Hours or Dollars
ACS ENG003 (Prof Engr A)	
ACS ENG004 (Prof Engr B)	
ACS BUS003 (Ops Finance)	
ACS TEC003 (Technician)	
ACS STD003 (Student)	
Aero ENG001 (Prof Engr A)	124
Aero ENG002 (Prof Engr B)	
Aero BUS001 (PP&C)	152
Aero TEC001 (Technician)	
Aero STD001 (Student)	

Travel	1,824	Cost with G&A Only
HLAB Purch w ACQ and G&A		Material Pass thru
Purch Services ACQ and G&A		Matl w HW Part No Full Burden
Interdivisional No Acq		Interdivisional w/Acq

Honeywell Labs
Cost Basis of Estimate (BOE)

	Program Name: AFCS1.5 Dist Air Space SYS	
Task/WBS Number: 2.2	**Prepared by:** Kevin Schweiker	**Date Prepared:** 8/13/2013
Task Title: Definition (Year 2)	**Approved by:** Pavan A	**Revision:**
SOW Ref:		**Period of Performance:** 12/10/14 1/20/15

Task Definition:

Extends the definition of terms and concepts from the first year's effort. The output of this task flows to Task 10.

Basis of Estimate / Thought Process and Assumptions:

Safety Terms and Concepts
Mathematical Casting of Terms and Concepts

Basis of Estimate / Actual History:

Program:

Yes: [ ]

No: [X]

Tally Number:

Actual Hours:

Period of Performance:

Extrapolation Methodology / Assumptions:

This estimate is based on the originator's best judgment, general knowledge and experience from performing similar tasks on other programs – estimated to entail approximately 1 full week hours of an A Engineer with a 2 day review by a second A Engineer.

Estimate (hours and material dollars):

	Hours or Dollars
ACS ENG003 (Prof Engr A)	
ACS ENG004 (Prof Engr B)	
ACS BUS003 (Ops Finance)	
ACS TEC003 (Technician)	
ACS STD003 (Student)	
Aero ENG001 (Prof Engr A)	56
Aero ENG002 (Prof Engr B)	
Aero BUS001 (PP&C)	
Aero TEC001 (Technician)	
Aero STD001 (Student)	

Travel	Cost with G&A Only
HLAB Purch w ACQ and G&A	Material Pass thru
Purch Services ACQ and G&A	Matl w HW Part No Full Burden
Interdivisional No Acq	Interdivisional w/Acq

Honeywell Labs
Cost Basis of Estimate (BOE)

	Program Name: AFCS1.5 Dist Air Space SYS	
Task/WBS Number: 2.3	**Prepared by:** Kevin Schweiker	**Date Prepared:** 8/13/2013
Task Title: Structures (Year 2)	**Approved by:** Pavan A	**Revision:**
SOW Ref:		**Period of Performance:** 12/10/14 1/20/15

Task Definition:

Extend the definition of structures defined in the first years effort. This output of this task flows to Task 10.

Basis of Estimate / Thought Process and Assumptions:

Safety Assessment methods
Mathematical Casting of Methods

Basis of Estimate / Actual History:

Program:	**Tally Number:**
Yes: [ ]	**Actual Hours:**
No: [X]	**Period of Performance:**

Extrapolation Methodology / Assumptions:

This estimate is based on the originator's best judgment, general knowledge and experience from performing similar tasks on other programs – estimated to entail approximately 1 full week hours of an A Engineer with a 2 day review by a second A Engineer. Suncontractor also reviews definition.

Estimate (hours and material dollars):

	Hours or Dollars
ACS ENG003 (Prof Engr A)	
ACS ENG004 (Prof Engr B)	
ACS BUS003 (Ops Finance)	
ACS TEC003 (Technician)	
ACS STD003 (Student)	
Aero ENG001 (Prof Engr A)	56
Aero ENG002 (Prof Engr B)	
Aero BUS001 (PP&C)	
Aero TEC001 (Technician)	
Aero STD001 (Student)	

Travel	Cost with G&A Only
HLAB Purch w ACQ and G&A	Material Pass thru
Purch Services ACQ and G&A	Matl w HW Part No Full Burden
Interdivisional No Acq	Interdivisional w/Acq

Honeywell Labs
Cost Basis of Estimate (BOE)

	Program Name: AFCS1.5 Dist Air Space SYS	
Task/WBS Number: 2.4	**Prepared by:** Kevin Schweiker	**Date Prepared:** 8/13/2013
Task Title: Category Theory (Year 2)	**Approved by:** Pavan A	**Revision:**
SOW Ref:		**Period of Performance:** 12/10/14 8/20/15

Task Definition:

This task extends the category-theoretic methods developed during the first year. This task has input from Tasks8and 9 and provides output to Task 12.

Basis of Estimate / Thought Process and Assumptions:

Definition of Category
Examples within Category
Brief Analysis of Category

Basis of Estimate / Actual History:

Program:	**Tally Number:**
Yes: [ ]	**Actual Hours:**
No: [X]	**Period of Performance:**

Extrapolation Methodology / Assumptions:

Segregated actual hours on similar tasks are not available

Estimate (hours and material dollars):

	Hours or Dollars
ACS ENG003 (Prof Engr A)	
ACS ENG004 (Prof Engr B)	
ACS BUS003 (Ops Finance)	
ACS TEC003 (Technician)	
ACS STD003 (Student)	
Aero ENG001 (Prof Engr A)	108
Aero ENG002 (Prof Engr B)	
Aero BUS001 (PP&C)	
Aero TEC001 (Technician)	
Aero STD001 (Student)	

Travel	Cost with G&A Only
HLAB Purch w ACQ and G&A	Material Pass thru
Purch Services ACQ and G&A	Matl w HW Part No Full Burden
Interdivisional No Acq	Interdivisional w/Acq

Honeywell Labs
Cost Basis of Estimate (BOE)

	Program Name: AFCS1.5 Dist Air Space SYS	
Task/WBS Number: 2.5	**Prepared by:** Kevin Schweiker	**Date Prepared:** 8/13/2013
Task Title: Examples/Case Studies (Year 2)	**Approved by:** Pavan A	**Revision:**
SOW Ref:		**Period of Performance:** 5/27/15 7/28/15

Task Definition:

Developssecond years example for analysis by the categoric-methods developed in Task 10. This serves as input for Task 12.

Basis of Estimate / Thought Process and Assumptions:

NextGen Example

Basis of Estimate / Actual History:

Program:		**Tally Number:**
Yes:		**Actual Hours:**
No:	X	**Period of Performance:**

Extrapolation Methodology / Assumptions:

This estimate is based on the originator's best judgment, general knowledge and experience from performing similar tasks on other programs – estimated to entail 7.5 days of an A Engineer effort.

The subcontractor will also provide input into the example.

Estimate (hours and material dollars):

	Hours or Dollars
ACS ENG003 (Prof Engr A)	
ACS ENG004 (Prof Engr B)	
ACS BUS003 (Ops Finance)	
ACS TEC003 (Technician)	
ACS STD003 (Student)	
Aero ENG001 (Prof Engr A)	60
Aero ENG002 (Prof Engr B)	
Aero BUS001 (PP&C)	
Aero TEC001 (Technician)	
Aero STD001 (Student)	

Travel	Cost with G&A Only
HLAB Purch w ACQ and G&A	Material Pass thru
Purch Services ACQ and G&A	Matl w HW Part No Full Burden
Interdivisional No Acq	Interdivisional w/Acq

Honeywell Labs
Cost Basis of Estimate (BOE)

	Program Name: AFCS1.5 Dist Air Space SYS	
Task/WBS Number: 2.6	**Prepared by:** Kevin Schweiker	**Date Prepared:** 8/13/2013
Task Title: Evaluation (Year 2)	**Approved by:** Pavan A	**Revision:**
SOW Ref:		**Period of Performance:** 8/19/15 11/19/15

Task Definition:

Evaluate impact of te category-theoretic methods in analyzing the NextGen example developed in Task11. Tasks 10 and 11 are inputs. The output will be incorporated in the second year's year-end report.

Basis of Estimate / Thought Process and Assumptions:

Evaluation of comms disruptions on Safe Separation Technical Report

Basis of Estimate / Actual History:

Program:

Yes: [ ]

No: [X]

Tally Number:

Actual Hours:

Period of Performance:

Extrapolation Methodology / Assumptions:

This estimate is based on the originator's best judgment, general knowledge and experience from performing similar tasks on other programs – estimated to entail 12 days of an A Engineer effort.

The subcontractor will also provide input into the example.

Estimate (hours and material dollars):

	Hours or Dollars
ACS ENG003 (Prof Engr A)	
ACS ENG004 (Prof Engr B)	
ACS BUS003 (Ops Finance)	
ACS TEC003 (Technician)	
ACS STD003 (Student)	
Aero ENG001 (Prof Engr A)	96
Aero ENG002 (Prof Engr B)	
Aero BUS001 (PP&C)	
Aero TEC001 (Technician)	
Aero STD001 (Student)	

Travel	Cost with G&A Only
HLAB Purch w ACQ and G&A	Material Pass thru
Purch Services ACQ and G&A	Matl w HW Part No Full Burden
Interdivisional No Acq	Interdivisional w/Acq

Honeywell Labs
Cost Basis of Estimate (BOE)

	Program Name: AFCS1.5 Dist Air Space SYS	
Task/WBS Number: 3.1	**Prepared by:** Kevin Schweiker	**Date Prepared:** 8/13/2013
Task Title: Administration (Year 3)	**Approved by:** Pavan A	**Revision:**
SOW Ref:		**Period of Performance:** 12/1/15 11/30/16

Task Definition:

This task captures all the Program management tasks, meetings and presentations to NASA for the third year of the program.

Basis of Estimate / Thought Process and Assumptions:

Program Management - Best judgement estimate 4 hrs per month to track internal spending and maintain Honeywell required documentation (risk registar, Earned Value managment, MOR Quad Charts. This estimate is an estimate based. Financial Analyst of 12 hr per month based on VVFCS TA 2.
Subconracts - Includes labor for face to face meeting with MIT Subcontractor. Assue one meeeting in February for two days
Set-up svn, collaborating environment, 2 hours
Year 3 Kick-off Presentation, LaRC - estimate of 8 hrs prep, conduct 1 day review at LaRC
Year 3, Q1 Report, Webcast - prep of 3 hours, conduct 1 hour webcast
Year 3, Q2 Report, Webcast - prep of 3 hours cconduct 1 hour webcast
Year 3, Q3 Report, Webcast - prep of 3 hrs, conduct 1 hr webcast
Year 3 Interim Report, Presentation LaRC, prep of 8 hrs, conduct 1 day review at LaRC

Basis of Estimate / Actual History:

Program:

Yes: [ ]

No: [X]

Tally Number:

Actual Hours:

Period of Performance:

Extrapolation Methodology / Assumptions:

This estimate is based on the originator's best judgment, general knowledge and experience from performing similar similar tasks on other programs.

Estimate (hours and material dollars):

	Hours or Dollars
ACS ENG003 (Prof Engr A)	
ACS ENG004 (Prof Engr B)	
ACS BUS003 (Ops Finance)	
ACS TEC003 (Technician)	
ACS STD003 (Student)	
Aero ENG001 (Prof Engr A)	124
Aero ENG002 (Prof Engr B)	
Aero BUS001 (PP&C)	152
Aero TEC001 (Technician)	
Aero STD001 (Student)	

Travel	1,887	Cost with G&A Only
HLAB Purch w ACQ and G&A		Material Pass thru
Purch Services ACQ and G&A		Matl w HW Part No Full Burden
Interdivisional No Acq		Interdivisional w/Acq

Honeywell Labs
Cost Basis of Estimate (BOE)

	Program Name: AFCS1.5 Dist Air Space SYS	
Task/WBS Number: 3.2	**Prepared by:** Kevin Schweiker	**Date Prepared:** 8/13/2013
Task Title: Definition (Year 3)	**Approved by:** Pavan A	**Revision:**
SOW Ref:		**Period of Performance:** 12/10/15 1/20/16

Task Definition:

Extends the definition of terms and concepts from the second year's effort. The output of this task flows to Task 16.

Basis of Estimate / Thought Process and Assumptions:

Safety Terms and Concepts
Mathematical Casting of Terms and Concepts

Basis of Estimate / Actual History:

Program:

Yes: [ ]

No: [X]

Tally Number:

Actual Hours:

Period of Performance:

Extrapolation Methodology / Assumptions:

This estimate is based on the originator's best judgment, general knowledge and experience from performing similar tasks on other programs – estimated to entail approximately 1 full week hours of an A Engineer with a 2 day review by a second A Engineer.

Estimate (hours and material dollars):

	Hours or Dollars
ACS ENG003 (Prof Engr A)	
ACS ENG004 (Prof Engr B)	
ACS BUS003 (Ops Finance)	
ACS TEC003 (Technician)	
ACS STD003 (Student)	
Aero ENG001 (Prof Engr A)	56
Aero ENG002 (Prof Engr B)	
Aero BUS001 (PP&C)	
Aero TEC001 (Technician)	
Aero STD001 (Student)	

Travel	Cost with G&A Only
HLAB Purch w ACQ and G&A	Material Pass thru
Purch Services ACQ and G&A	Matl w HW Part No Full Burden
Interdivisional No Acq	Interdivisional w/Acq

Honeywell Labs
Cost Basis of Estimate (BOE)

	Program Name: AFCS1.5 Dist Air Space SYS	
Task/WBS Number: 3.3	**Prepared by:** Kevin Schweiker	**Date Prepared:** 8/13/2013
Task Title: Structures (Year 3)	**Approved by:** Pavan A	**Revision:**
SOW Ref:		**Period of Performance:** 12/10/15 1/20/16

Task Definition:

Extend the definition of structures defined in the second years effort. This output of this task flows to Task 16.

Basis of Estimate / Thought Process and Assumptions:

Safety Assessment methods
Mathematical Casting of Methods

Basis of Estimate / Actual History:

Program:	**Tally Number:**
Yes: [ ]	**Actual Hours:**
No: [X]	**Period of Performance:**

Extrapolation Methodology / Assumptions:

This estimate is based on the originator's best judgment, general knowledge and experience from performing similar tasks on other programs – estimated to entail approximately 1 full week hours of an A Engineer with a 2 day review by a second A Engineer. Suncontractor also reviews definition.

Estimate (hours and material dollars):

	Hours or Dollars
ACS ENG003 (Prof Engr A)	
ACS ENG004 (Prof Engr B)	
ACS BUS003 (Ops Finance)	
ACS TEC003 (Technician)	
ACS STD003 (Student)	
Aero ENG001 (Prof Engr A)	56
Aero ENG002 (Prof Engr B)	
Aero BUS001 (PP&C)	
Aero TEC001 (Technician)	
Aero STD001 (Student)	

Travel	Cost with G&A Only
HLAB Purch w ACQ and G&A	Material Pass thru
Purch Services ACQ and G&A	Matl w HW Part No Full Burden
Interdivisional No Acq	Interdivisional w/Acq

Honeywell Labs
Cost Basis of Estimate (BOE)

	Program Name: AFCS1.5 Dist Air Space SYS	
Task/WBS Number: 3.4	**Prepared by:** Kevin Schweiker	**Date Prepared:** 8/13/2013
Task Title: Category Theory (Year 3)	**Approved by:** Pavan A	**Revision:**
SOW Ref:		**Period of Performance:** 12/10/15 8/17/16

Task Definition:

This task extends the category-theoretic methods developed during the first year. This task has input from Tasks 14 and 15, and provides output to Task 18.

Basis of Estimate / Thought Process and Assumptions:

Definition of Category
Examples within Category
Brief Analysis of Category

Basis of Estimate / Actual History:

Program:	**Tally Number:**
Yes: [ ]	**Actual Hours:**
No: [X]	**Period of Performance:**

Extrapolation Methodology / Assumptions:

This estimate is based on the originator's best judgment, general knowledge and experience from performing similar tasks on other programs – estimated to entail 13.5 days of an A Engineer effort.
The subcontractor will also provide input into the example.

Estimate (hours and material dollars):

	Hours or Dollars
ACS ENG003 (Prof Engr A)	
ACS ENG004 (Prof Engr B)	
ACS BUS003 (Ops Finance)	
ACS TEC003 (Technician)	
ACS STD003 (Student)	
Aero ENG001 (Prof Engr A)	108
Aero ENG002 (Prof Engr B)	
Aero BUS001 (PP&C)	
Aero TEC001 (Technician)	
Aero STD001 (Student)	

Travel	Cost with G&A Only
HLAB Purch w ACQ and G&A	Material Pass thru
Purch Services ACQ and G&A	Matl w HW Part No Full Burden
Interdivisional No Acq	Interdivisional w/Acq

Honeywell Labs
Cost Basis of Estimate (BOE)

	Program Name: AFCS1.5 Dist Air Space SYS	
Task/WBS Number: 3.5	**Prepared by:** Kevin Schweiker	**Date Prepared:** 8/13/2013
Task Title: Examples/Case Studies (Year 3)	**Approved by:** Pavan A	**Revision:**
SOW Ref:		**Period of Performance:** 5/26/16 7/27/16

Task Definition:

Basis of Estimate / Thought Process and Assumptions:

NextGen Example

Basis of Estimate / Actual History:

Program:

Yes: [ ]

No: [X]

Tally Number:

Actual Hours:

Period of Performance:

Extrapolation Methodology / Assumptions:

Segregated actual hours on similar tasks are not available

Estimate (hours and material dollars):

	Hours or Dollars
ACS ENG003 (Prof Engr A)	
ACS ENG004 (Prof Engr B)	
ACS BUS003 (Ops Finance)	
ACS TEC003 (Technician)	
ACS STD003 (Student)	
Aero ENG001 (Prof Engr A)	72
Aero ENG002 (Prof Engr B)	
Aero BUS001 (PP&C)	
Aero TEC001 (Technician)	
Aero STD001 (Student)	

Travel	Cost with G&A Only
HLAB Purch w ACQ and G&A	Material Pass thru
Purch Services ACQ and G&A	Matl w HW Part No Full Burden
Interdivisional No Acq	Interdivisional w/Acq

Honeywell Labs
Cost Basis of Estimate (BOE)

	Program Name: AFCS1.5 Dist Air Space SYS	
Task/WBS Number: 3.6	**Prepared by:** Kevin Schweiker	**Date Prepared:** 8/13/2013
Task Title: Evaluation (Year 3)	**Approved by:** Pavan A	**Revision:**
SOW Ref:		**Period of Performance:** 8/18/16 11/9/16

Task Definition:

Evaluate impact of te category-theoretic methods in analyzing the NextGen example developed in Task17. Tasks 16 and 17 are inputs. The output will be incorporated in the second year's year-end report. An article will be written on our findngs and published in an approaprriate forum.

Basis of Estimate / Thought Process and Assumptions:

Evaluation of comms disruptions on Safe Separation
Technical Report
Published acedemic paper on applications of Category theory to the stusy of SoS.

Basis of Estimate / Actual History:

Program:

Yes: [ ]

No: [X]

Tally Number:

Actual Hours:

Period of Performance:

Extrapolation Methodology / Assumptions:

This estimate is based on the originator's best judgment, general knowledge and experience from performing similar tasks on other programs – estimated to entail 12 days of an A Engineer effort.
The subcontractor will also provide input into the evaluation and co-author a publication.

Estimate (hours and material dollars):

	Hours or Dollars
ACS ENG003 (Prof Engr A)	
ACS ENG004 (Prof Engr B)	
ACS BUS003 (Ops Finance)	
ACS TEC003 (Technician)	
ACS STD003 (Student)	
Aero ENG001 (Prof Engr A)	96
Aero ENG002 (Prof Engr B)	
Aero BUS001 (PP&C)	
Aero TEC001 (Technician)	
Aero STD001 (Student)	

Travel	Cost with G&A Only
HLAB Purch w ACQ and G&A	Material Pass thru
Purch Services ACQ and G&A	Matl w HW Part No Full Burden
Interdivisional No Acq	Interdivisional w/Acq

Honeywell Labs
Cost Basis of Estimate (BOE)

	Program Name: AFCS1.5 Dist Air Space SYS	
Task/WBS Number: 1.7	**Prepared by:** Kevin Schweiker	**Date Prepared:** 8/13/2013
Task Title: MIT	**Approved by:** Pavan A	**Revision:**
		Period of Performance: 12/2/13 11/30/14
SOW Ref:		

Task Definition:

MIT's first year effort to develop and evaluate category theory and support Honeywell with object and structure definitions.

Basis of Estimate / Thought Process and Assumptions:

Proposal from MIT.

Basis of Estimate / Actual History:

Program:

Yes: [ ]

No: [X]

Tally Number:
Actual Hours:
Period of Performance:

Extrapolation Methodology / Assumptions:

Segregated actual hours on similar tasks are not available

Estimate (hours and material dollars):

	Hours or Dollars
ACS ENG003 (Prof Engr A)	
ACS ENG004 (Prof Engr B)	
ACS BUS003 (Ops Finance)	
ACS TEC003 (Technician)	
ACS STD003 (Student)	
Aero ENG001 (Prof Engr A)	
Aero ENG002 (Prof Engr B)	
Aero BUS001 (PP&C)	
Aero TEC001 (Technician)	
Aero STD001 (Student)	

Travel			Cost with G&A Only
HLAB Purch w ACQ and G&A	100,000		Material Pass thru
Purch Services ACQ and G&A			Matl w HW Part No Full Burden
Interdivisional No Acq			Interdivisional w/Acq

Honeywell Labs
Cost Basis of Estimate (BOE)

	Program Name: AFCS1.5 Dist Air Space SYS	
Task/WBS Number: 2.7	**Prepared by:** Kevin Schweiker	**Date Prepared:** 8/13/2013
Task Title: MIT	**Approved by:** Pavan A	**Revision:**
		Period of Performance: 12/2/14 11/30/15
SOW Ref:		

Task Definition:

MIT's second year effort to develop and evaluate category theory and support Honeywell with object and structure definitions.

Basis of Estimate / Thought Process and Assumptions:

Proposal from MIT.

Basis of Estimate / Actual History:

Program:

Yes: [ ]

No: [X]

Tally Number:
Actual Hours:
Period of Performance:

Extrapolation Methodology / Assumptions:

Segregated actual hours on similar tasks are not available

Estimate (hours and material dollars):

Hours or Dollars

ACS ENG003 (Prof Engr A)
ACS ENG004 (Prof Engr B)
ACS BUS003 (Ops Finance)
ACS TEC003 (Technician)
ACS STD003 (Student)

Aero ENG001 (Prof Engr A)
Aero ENG002 (Prof Engr B)
Aero BUS001 (PP&C)
Aero TEC001 (Technician)
Aero STD001 (Student)

Travel		Cost with G&A Only	
HLAB Purch w ACQ and G&A	100,000	Material Pass thru	
Purch Services ACQ and G&A		Matl w HW Part No Full Burden	
Interdivisional No Acq		Interdivisional w/Acq	

Honeywell Labs
Cost Basis of Estimate (BOE)

	Program Name: AFCS1.5 Dist Air Space SYS	
Task/WBS Number: 3.7	**Prepared by:** Kevin Schweiker	**Date Prepared:** 8/13/2013
Task Title: MIT	**Approved by:** Pavan A	**Revision:**
		Period of Performance: 12/2/15 11/30/16
SOW Ref:		

Task Definition:

MIT's third year effort to develop and evaluate category theory and support Honeywell with object and structure definitions.

Basis of Estimate / Thought Process and Assumptions:

Proposal from MIT.

Basis of Estimate / Actual History:

Program:

Yes: [ ]

No: [X]

Tally Number:

Actual Hours:

Period of Performance:

Extrapolation Methodology / Assumptions:

Segregated actual hours on similar tasks are not available

Estimate (hours and material dollars):

	Hours or Dollars
ACS ENG003 (Prof Engr A)	
ACS ENG004 (Prof Engr B)	
ACS BUS003 (Ops Finance)	
ACS TEC003 (Technician)	
ACS STD003 (Student)	
Aero ENG001 (Prof Engr A)	
Aero ENG002 (Prof Engr B)	
Aero BUS001 (PP&C)	
Aero TEC001 (Technician)	
Aero STD001 (Student)	

Travel			Cost with G&A Only
HLAB Purch w ACQ and G&A	100,000		Material Pass thru
Purch Services ACQ and G&A			Matl w HW Part No Full Burden
Interdivisional No Acq			Interdivisional w/Acq

9. Special Notices

Honeywell

111 S 34th Street
P.O. Box 85181
Phoenix, AZ 85034

September 4, 2013

National Aeronautics and Space Administration (NASA) Headquarters
Aeronautics Research Mission Directorate
Attn: Susan Minor, Deputy Director, Integration and Management Office
300 E Street, SW
Washington, DC 20546-0001

Attention: Patent Attorney

Subject: Petition for Advance Waiver of Patent Rights under NASA Research Announcement (NRA): NNH13ZEA001N

References: Research Opportunities in Aeronautics – 2013 (ROA-2013)
NASA Research Announcement (NRA): NNH13ZEA001N
Leading Edge Aeronautics Research for NASA (LEARN)
Amendment No. 3
Honeywell response to System-Wide Safety assurance Technology Project (SSAT1), Appendix B.2 Subtopic # AFCS1.5, Distributed Systems: Distributed Airspace Systems.

Dear NASA Representative:

On behalf of Honeywell International Inc., the undersigned submits this PETITION FOR WAIVER OF PATENT RIGHTS. Pursuant to 14 CFR 1245.110, the following information is submitted:

1. Petitioner:
   Honeywell International Inc.
   Honeywell Laboratories
   3660 Technology Drive
   Minneapolis, MN 55418
2. Petitioner is represented by the following counsel:
   Kurt Luther. 602-436-0464, or
   Dina Khaled. 612-951-6196
3. Citation to the 14 CFR section(s) under which waiver is sought:
   1245.104; advance waiver
4. The petitioner is the NASA contractor.
5. Identification of the NASA contract under which waiver is sought:
   NASA Research Announcement (NRA) NNH13ZEA001N; Research Opportunities in Aeronautics – 2013 (ROA-2013).

6. Designation of countries in which waiver of patent rights is desired:
7. United States of America; and foreign rights for Canada, Japan, France, Great Britain, Germany, the European Patent Convention (EP), and countries included in the Patent Cooperation Treaty (PCT).
8. No inventions identified at this time; request is for an advance waiver of all inventions created under the identified contract.
9. Name address and telephone number of party to whom the Inventions and Contributions board is to communicate when the Petition is acted upon, i.e., to whom the Instrument of Waiver is to be sent.

   Honeywell International Inc.
   Attn: Bill Thomas
   111 S. 34th Street, M/S 121
   Phoenix, Arizona 85034
   602-231-3061

The petitioner is neither an entity of, nor under the control of, a foreign government.

Sincerely,
HONEYWELL INTERNATIONAL INC.
Aerospace Defense and Space

Bill Thomas
Sr. Contract Manager
Advanced Technology Programs
Office: 602-231-3061
Mobile: 480-414-0191
Fax: 602-231-1353
email: william.thomas2@honeywell.com