MONA Framework for Leading Change: The Small Satellite Paradigm

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ABSTRACT

It is imperative for the United States Air Force to find innovative solutions for more affordable and resilient warfighting capabilities. The ever tightening budget environment is driving an unprecedented need for new material solutions which are more affordable, and resilient, yet deliver the same or better capability. The Air Force Space and Missile Systems Center (SMC) Chief Scientist has initiated a Modular Open Networked Architecture (MONA) framework to create new material solutions meeting this need and ensuring the material solutions abide by Department of Defense requirements for modularity, interoperability and net centricity. This paper outlines the benefits and characteristics of a MONA system, with a focus on the software architecture that enables MONA. The paper will highlight the resources available, process of implementation, and lessons learned from the Standard Network Adapter for Payloads (SNAP) implementation. Finally, the paper presents ways in which the small satellite community can participate in the technology development and risk reduction necessary to mature this technology for all spaceflight systems. The small satellite community can play an important role in the transition of MONA from demonstration to flight-proven capability. Small satellites of all form factors represent a cost effective environment to buy down the risk of a modular open network architecture for space systems and lessen the impact of the non recurring engineering necessary to implement the framework.

BACKGROUND

The Air Force Space and Missile Systems Center (SMC) Chief Scientist, in 2012, initiated a Modular Open Networked Architecture (MONA) framework to create new concepts meeting the need and ensuring potential material solutions abide by Department of Defense Requirements for modularity, interoperability and net centricity.

The Department of Defense has been moving policy guidance in the direction of a MONA framework for some time. In May 2003, the Department of Defense issued a requirement (DoDD 5000.1) for modular, open-systems approaches to be employed wherever feasible. In December 2004, the Department of Defense issued a requirement (DoDD 8320.2) for net-centric data strategies.

In January of 2013 the SNAP demonstration effort began. On 21 January 2014 the first MONA industry workshop was held to demonstrate the principles, discuss concepts and assess the feasibility of MONA and to out brief to industry the SNAP demonstrator. Industry was able to directly observe and discuss many benefits in reduced cost, reduced timelines, and more flexible, adaptable systems that could be very useful in space architectures using the MONA and SNAP approaches.

The results from the workshop survey were overwhelmingly positive and reflected there is sufficient maturity to begin MONA implementation in spaceflight programs through flight qualification and flight demonstration. Moving forward, the government would like to initiate and encourage consensus industry standards to bring about MONA. The government can also provide a baseline reference implementation freely available to industry to further encourage the transition to a MONA approach based on government's previous research and development investments.

OVERVIEW

The MONA framework for change is based on the John P. Kotter[1] approach to leading change. The leading change formalism is loosely an action plan, normally applied to industry, to "lead" to a new end point, not "manage" an organization to a new end point. Due to this emphasis on "leading the change", various aspects of management will not be addressed by MONA. The emphasis of "leading" change is appropriate for MONA because MONA will never be a specific program or funded entity itself, but rather an approach multiple programs can implement within their own management structures. MONA is ideal for application across a portfolio, such as the National Security Space portfolio which is composed of many separate programs which at some level should work together to deliver greater capability. The situation today is that each program is delivering capability separately.

MONA is and will remain a framework for change which can be implemented on those programs operating under existing management structures. In the case of the government acquisition structure, the management approach is primarily rooted in the DoD 5000.02. MONA can be directly overlaid on 5000.02 without changing any aspects of the existing program management paradigm. In some cases the 5000.02 calls for some aspects of MONA, such as modularity and openness, but not MONA directly. It is possible that balancing the leadership and management functions might produce better outcomes for the acquisition community.

The Kotter methodology is taught widely across the senior government community and was used in the scenario based PMT 400 Program Management Training from Defense Acquisition University (DAU). The particular version of Kotter, used for this effort, was from the 2007 class studies conducted by one of the authors. Based on the DAU faculty assessments, Kotter is widely used by industry because it gets results. Since the government acquisition community is so tightly intertwined with the industrial community it seemed reasonable to adopt the industry approach approved by DAU and modify it to fit the context of the problems faced by the space acquisition community. It is also more likely that industry will be more accepting of a government change framework that is directly borrowed from industry in the first place.

The Chief Scientist modified Kotter's change sequence slightly. This is permissible according to Kotter as long as all the stages are accomplished without major gaps between them and are all addressed in roughly the order presented. For MONA, the approach was changed by swapping stages 2 and 3 of the 8 stages. This was done due to the leadership and management hierarchy presented by the government, primarily the military (USAF) oversight structure itself. It became apparent that without first developing the vision and the strategy, the senior officers necessary to form the guiding coalition could not be engaged. The senior personnel needed to be presented with courses of action (COA) (equivalent to the vision and strategy step products) to which they could then decide whether or not to participate in the guiding coalition. The military personnel do not create a guiding coalition and then look for a COA.

What follows is the explanation and application of the 8 stages of the Kotter methodology, adapted for the MONA application and providing the key lessons learned.

ESTABLISH A SENSE OF URGENCY

People and organizations need a sense of urgency in order to bring about change. The urgency is tied to the statement of the problem and the constraints surrounding the problem. The MONA sense of urgency is partly based on a perceived shortfall in the acquisition community for delivering affordable and timely government space systems. It is also partly based in the author's belief there is a major opportunity to use MONA to create a more capable National Security Space enterprise.

First, based on the perception that the acquisition community has failed at delivering projects that meet cost, schedule and performance baselines, the urgency stage appeared to have a substantial foundation. This perception is documented in numerous reports from the GAO extending back many years. Some of the key reports are cited here. According to the GAO, "Assessments of Selected Weapons Programs, Mar 2007 and GAO Testimony Before US Senate Subcommittee: Space Acquisitions, March 2008 (SBIRS)"[2,3], there is a 32.3% cost growth and 7 year delay for major [space] systems acquisitions. This has not materially changed in the intervening years[4,5].

Second, advances in science and technology are presenting new options for designing modular and open systems that are based on net centric, or packetized protocol approaches to moving data throughout larger systems. By marrying the net centric features to the modular and open features, MONA presents a new opportunity for NSS to take advantage of large investments already made in the information technology community. The NSS should take advantage of this opportunity, and the key shortfalls that will be overcome by doing so were outlined by the USAF Chief Scientist, Dr Mica Endsley at the MONA SNAP Workshop on 21 January 2014. The following is a brief summary of those perspectives.

Air Force Scientific and Technical Perspectives

Current space systems development and delivery is characterized by several key features. Development is drawn out over time. It is not uncommon for a program to be 10 years in the making and 20 years on orbit. The draw out in the development and acquisition phase creates expensive programs with standing armies of workers building craftsman quality, handbuilt and unique systems.

Often to obtain the performance, both capability and Size Weight and Power (SWAP) of the systems, the prime integrator of the space craft will create a tightly integrated, one-of a kind system which leads to further expense to upgrade. Engineering changes which have to be made while building a system over a 10 year period are likewise very expensive. Space craft have traditionally had to work to lowest volume, lowest weight due to the high cost to reach orbit. Hence for a single spacecraft buy, there was not an adequate business case for the SWAP penalty of the modular infrastructure.

Due to the poor ability to integrate different platforms and systems developed over time, spacecraft components are in a state of flux for the suppliers and the integrators must carry resources to cover the risks as suppliers come into and out of the supplier pool over the 10 year period.

The systems suffer from low technical agility, a form of resilience—with no opportunity to inject new technologies for long periods of time, typically a decade or more. The designs are launched with outdated technologies already lagging the development of threats which can evolve over much shorter periods. This can mean that threat or stressors which were not designed for during the 10 years prior to launch will be present. The threats then evolve at great speed after launch and for the remaining 20 year lifetimes.

There is an inability to upgrade parts of the system, and when major changes are absolute necessary the change cuts across more of the design. Lastly, for obvious reasons, it is cost prohibitive today to modify spacecraft on orbit. Though DARPA and other advanced technology developers are looking at means for bringing about on-orbit upgrades, refueling and line replacement of units, these capabilities will not be available for some time.

It is possible that an on-orbit debris collision event could accelerate the investments in technology needed to conduct active debris mitigation efforts in the future. These investments may provide a sufficient business case and risk reduction for many of the on-orbit technologies which could be used to upgrade or modify future spacecraft.

Policy and Guidance

There are numerous policy and guidance initiatives over the years which steadily have made the case for the necessity of pursuing modular, open and networked architectures. The DoDI 5000.02: Operation of the Defense Acquisition System cites the need to be modular and open where feasible. The underlying reason is that this allows rapid reconfiguration of warfighting capability into new warfighting configurations when threats evolve.

DoDD 8320.02: "Data Sharing in a Net-Centric DoD" was devised to ensure that data created in the battlesphere regardless of source, could be shared for the benefit of all warfighters in the battlesphere. By ensuring interoperability of data and software architectures the warfighter is not tied to a specific hardware solution and can more rapidly evolve with the threat.

The CJCSI 6212.01F: "Net Ready KPPs" (and subsequent updates) seeks to put the net centric systems emphasis into the requirements process to encourage the key performance parameters for data sharing to be put into the design tradespace with the mission centric performance parameters. In some cases, especially with cyber intensive systems, the net ready KPPs are becoming an even more powerful vehicle for bringing about change.

In 2013, Better Buying Power 2.0 was released which called out the need for modular and open systems. The arguments for doing so correlate directly to those arguments discussed in the Air Force Science and Technical section and need not be repeated here. The Better Buying Power initiative is very compelling as it aims at the heart of the acquisition paradigm—how to obtain greater affordability and resilience for warfighting systems.

In sum, the sense of urgency for bringing about change is apparent on multiple fronts. Formal assessments of DoD acquisition performance, AF Technical Guidance and Acquisition Policy and Guidance add to a compelling case for change. The evidence seems to point towards a MONA approach as being a possible framework for meeting these needs.

DEVELOPING A VISION AND STRATEGY

The MONA Vision is a natural architectural progression from **m**odular to **o**pen to **n**etworked (M=>O=>N). Today in the space community there are numerous proprietary modular systems available from all the major prime integrating contractors and the commercial space craft builders. Open architectures are only beginning to take hold but are showing some promise at the lowest hardware level and at the highest application ("apps") levels in the software architectures. The middle layers are still proprietary. Currently there are NO packetized network protocol NSS operational space craft. So the strategy for MONA is to use existing modular approaches as a jumping off point and then ensure appropriate incentives could be devised to bring to bear human tendencies and group behaviors to benefit the progression to greater openness and networked features. This can be accomplished with an actionable vision described as follows.

Leverage existing investments in physical/electro mechanical **M**odularity already present in many spacecraft designs. These are evident in small form factor spacecraft as well. An example is the Ball Aerospace Standard Interface Vehicle used by the DoD Space Test Program. Another example is cubesats which adhere to the Cal Poly P-Pod standards. A few modular approaches are interconnect approaches which allow box to box connectivity and others are software architecture based. Examples are offshoots of the USAF AFRL Space Plug and Play Architecture, SPA.

Grow "**O**peness" through carefully chosen interfaces and subsequent standards with a preference for industry derived consensus standards. Openess is evident in the cubesat implementations, likely due to the collaborative needs to get many separate craft into integrated launch configurations in the shortest time. Openess is also evident in the rise of the ESPA class adapters and in the payload to bus interfaces used by the DoD Space Test Program.

GAO Report 13-651: Defense Acquisitions: "DOD Efforts to Adopt Open Systems…"[6] outlined the GAO perspective on how the services have created modular UAV systems. The NAVY has led the way in modularity, with successes at building modular open payloads. The USAF however, did not include modular open approaches in its first UAV purchases. The USAF now needs to go back and rethink their non-modular and closed designs, which are viewed as too expensive. Ideally openness should manifest as license free intellectual property at the interfaces which ensures a lower barrier to entry for the innovators.

Lastly, transition national investments in **N**etworked/information technology systems (IT) for more rapid modernization and to partially overcome the shortfall in space native STEM talent. The US still leads the world in the application and evolution of the information/knowledge sphere. This IT talent pool will also be the human foundation for the modernization for space cyber infrastructure which is underway in AF Space Command.

The MONA Strategy is one already familiar to many: **"Step-In/Step Out" (SISO).** It is an application of the role of government derived from the Constitutional Preamble to "promote the general welfare" wherein the government incentivizes a change to bring about an improvement for the public good. This technique has been particularly useful for infrastructure investments designed to benefit large sectors of industry and the public at large. Examples are numerous.

The U.S. government played a vital role in settling the West, including massive land purchases and giveaways, the Homestead Act, the Pony Express, agricultural colleges, rural electrification, telephone wiring, road-building, irrigation, and dam-building,

Eisenhower's Interstate Highway Program: This massive 1950s program paved an entire continent with highways, bringing undreamed of economic change, and allowing the middle class to resettle from the cities to the suburbs. As a dual use benefit, the original concrete versions of the highways were designed to accept the landing weight of unladen strategic nuclear bombers, should there be a nuclear exchange and all the US military airfields were destroyed.

The US based "intermodal" system which permits ship to rail to truck transfers of standardized 53 ft transport containers. This effort was undertaken by the government to more rapidly move war materials from coast to coast to lower the need and overhead cost to store war materials on both coasts for rapid response to conflicts abroad. (The assumption is that two large scale theaters like WWII would not occur simultaneously.) It further utilized the Eisenhower road systems, government sponsored rail and ship and port investments. Its dual use are clearly evident. US consumers obtained increased access to goods from around the world at lower prices and incentivized global economic growth.

Probably most importantly, the government incentivized the Internet. In the 1960s, the government created ARPANET, which was used and developed by the Defense Department, public universities and other research organizations. In 1985, the National Science Foundation created various supercomputing centers around the country, linking the five largest together to start the modern Internet of today.

Assuming SISO is appropriate for MONA what are the mini strategies to nudging the process towards success? The government must **Join** the consensus building and where appropriate **nudge** the process.

Get onto the **leading edge** with DoD Architectural Concepts and Needs and conduct high fidelity analysis showing where the highest payoffs are.

Coordinate and Consult with the people who will make it happen: industry—RFI results, surveys, IRAD process, etc.

Monitor Market Progress including civil, commercial and international defense industrial base products. This can be done by monitoring the numerous space vehicle efforts spawned from the ORS Modular Space Vehicle from Northrop Grumman, the Eagle M, and the Boeing Phantom Phoenix for example.

Then government will **"step out"** and let industry "run with it". Ideally Industry should develop and maintain the consensus standards on a continuous basis. Industry can then develop and provide the enabling components by ensuring sub tier suppliers get the key signals to develop and sell the necessary components. Industry to develop and provide an affordable means to confirm MONA components adhere to standards. Any standard that is too onerous or costly to administer will be a non starter with the community. This implies that a standard that is too strict or not license free will not be acceptable.

The good news is that government and industry are already accomplishing many of these mini strategies. As of this writing, there is an industry effort to establish the Consortium for Space Interface Standards (CSIS). CSIS is an offspring off the government funded Space Universal Modular (SUMO) architecture effort. CSIS is described in more detail in the next section.

CREATE THE GUIDING COALITION

Change requires the collective energy and participation of a community for success. Pulling together a group with enough power to lead change and getting them to work as a team is always a challenge. In this case the coalition can be drawn from the National Security Space stakeholder set, which includes key industrial base partners, government entities and research and development organizations across government, industry and academia. To begin creating the coalition for MONA, the government began to buy down the non-recurring engineering (NRE) costs starting in 2004 with the AFRL investments in space plug and play architectures. From 2004-2014 AFRL invested approximately $130M to devise a modular and open approach to spacecraft avionics. In 2006, the Operationally Responsive Space Office was stood up and has invested approximately $50M over the years in key capabilities which equate to faster integration and operability for space missions. In 2007, DARPA kicked off the F6, which is coming to a close in 2014 with an investment of approximately $70M in advanced technology for modular open space craft systems. Many companies received the benefits of these government investments over the years, while simultaneously preparing themselves for future commercialization and development of the technology. These are examples of the government stepping in.

The investments in technology did not go unnoticed by the systems engineers and architects. Across the NSS community, additional studies and business case exploration have gained momentum. Most recently the Space Universal Modular Architecture (SUMO) effort leveraged approximately $2M in business case/ROI, architecting analysis, and consensus standards analysis. The guiding coalition is getting comfortable with the basic idea that if 2 or more flight units are going to be built for a mission, the business case to employ modular and open interfaces will close with margin. Again, if only one space vehicle is envisioned for a particular implementation, it does not make business sense to invest in the infrastructure expenses for employing a modular and open interface. However, those single space craft are such large and lucrative targets in the budget and to the adversary, planners should consider having MONA back up options available.

The SUMO effort has since spawned additional industry working/steering groups to investigate specific business case scenarios and to explore industry consensus standards. Industry is leveraging the professional societies for standards development and using these professional bodies for providing a platform for training to ensure widest dissemination amongst the aerospace engineering professional community. By working with AIAA and NASA Common Instrument Interface (CII) approaches/strategy CSIS can definitely jump start consensus building for modular open standards.

CSIS current objective is "Pursuing and adopting global standards for open and modular spacecraft architecture. This will improve US space industrial base competitiveness, reduce the cost of satellites, encourage international trade, remove standards-related non-tariff barriers to trade, and increase satellite industrial innovation."

The CSIS is developing a standards framework and has established a multi-track plan based on the government's Integrated Transition Team (ITT) model, to bring the consensus standards on line. Figure 1 depicts the start of the standards framework and will surely change as industry tailors the government version to their use. The key features of Figure 1 are that the color codes loosely indicate the level of maturity and hence where early victories are to be had, and where more foundational work is required.

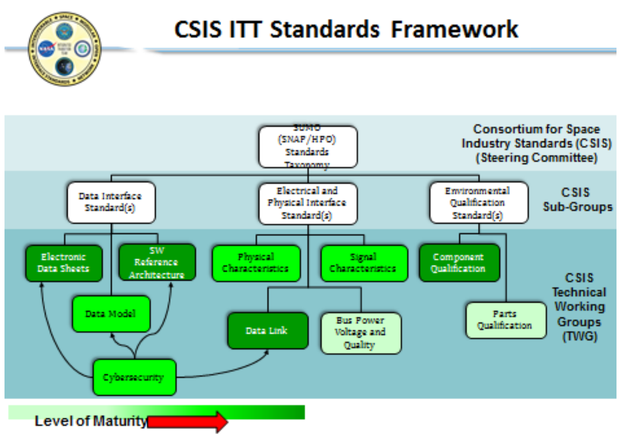

Figure 1 Possible Standards Framework for Establishing Consensus Industry Standards

Figure 2 Depicts a multi-track approach proposed by the ITT and modified by SMC XR to reflect a possible use by the Hosted Payload Office.

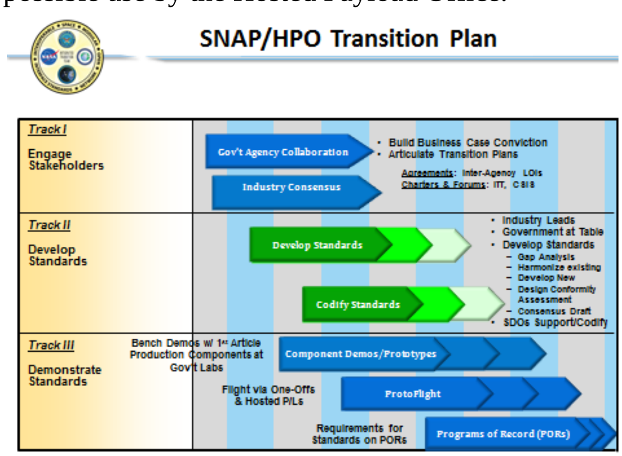

Figure 2 Timing and Flow for Establishing Consensus Standards for MONA like Activities

The basic idea is to instantiate a hosted payload interface paradigm for military payloads to be hosted on various spacecraft quickly and with minimal NRE. Hosted payloads offer another great opportunity to develop MONA frameworks for more affordable and resilient capability delivery.

COMMUNICATING THE CHANGE VISION

At numerous workshops, conferences and industry association meetings, affordability and resilience topics continue to gain ground and air time. The National Space Symposium 2014 showcased the need for the ORS space principles to be instilled across the NSS enterprise. ORS is one of the key parents of the MONA and with MONA inspired an exciting effort called SNAP.

In conjunction with the Space Dynamics Laboratory at Utah State University, the SMC's Development Planning Directorate (XR) demonstrated an adapter between diverse hosted payloads and a spacecraft bus. The demonstration was successfully conducted on 20 November 2013 utilizing the ORS MSV testbed located at the Northrop Grumman Corporation in Redondo Beach, California. The SNAP ground demonstration showcased the ability to interface multiple payload types with multiple spacecraft vehicles. Figure 3 depicts the basic SNAP demonstration overview.

Figure 3 The SNAP Demonstration Overview[9]

A specific outcome of the ground demonstration is a flight-ready version of SNAP software that can be utilized for a follow-on on-orbit demonstration. The SNAP software supports both Linux and VxWorks

Operating Systems. The demonstration entailed three different simulated hosted payloads and quantified the integration time for each payload. The SNAP unit demonstrated that a payload with a Mil-Std-1553, RS-422, or SpaceWire connection can successfully, rapidly, interface with a spacecraft that provides one of these connections[8].

SNAP showcased achievable costs savings enabled by standardization which further reduced testing timelines. The Northrop Grumman MSV team provided key insights as to how the SNAP approach showed them how to shorten integration times from months and weeks down to hours. This time savings in assembly, integration and testing (AIT) translates directly into cost savings for the customer and provides one of the key business case arguments for supporting a MONA framework.

After the 21 November SNAP demonstration to key SMC personnel, it was decided to have a workshop to share the results of MONA with the larger community. On 21 January 2014, the SMC Chief Scientist and the Aerospace Corporation hosted the MONA/SNAP Workshop. A full day of live demonstrations, Q and A on the MONA framework and SNAP demonstration culminated in an on-site survey which was overwhelmingly positive. Industry, including commercial space craft providers indicated they could support the MONA/SNAP paradigm.

In March 2014, Aerospace hosted the Ground Systems Architecture Workshops and once again MONA and SNAP were presented and received thumbs up from industry and academia. The ground architecture community acceptance along with the spacecraft community allows an integrated solution across the space ground link and recognizes that the integrated solution is necessary for MONA to realize its full potential. One can visualize more agile and affordable ground systems with more open options for establishing and optimizing the ground space links not only for satellite operations but also mission data operations.

There are numerous "Role Models/Pilot Programs" both past, present and in the future which will enable the MONA paradigm to reach fruition and communicate the change vision in the most important way—they are real hardware efforts. To name a few, the ORS Modular Space Vehicle, the STP Standard Interface Vehicle, the HPO Hosted Payload Interface Unit, the UAV/UAS/RPA /FLEX (Air and Munitions) program and OMS Open Mission Systems (modular avionics and software).

EMPOWERING BROAD BASED ACTION

At this point in the change process leadership has done what it can to provide proper conditions for the change and now must make the most difficult leadership decision of all: Empowerment. The empowerment concept is verbalized often but rarely fully flowers. It requires leadership to give up ownership and let the larger community rise to the vision by encouraging ideas, activities and actions to lower barriers to entry and share the power of leadership. For MONA the larger community is empowered and poised to move on four fronts. 1) physical modularity, that allows us to add or replace capabilities (to adapt to a new or customized interface, for example), 2) software modularity, which is true modularity with hardware independence – a huge step for the space community, 3) open, non-proprietary standards, so each of the system integrators can have access to the infrastructure and build on the stronger and more competitive sub tier capabilities, and 4) network-centric software that takes advantage of the Internet Protocol investments. There are more precise subgoals for each of these 4 fronts and expertise exists to mature each of them.

Software Modularity

- Truly hardware independent
- Adapts to changes with electronic ICDs
- Standard interfaces
- Fully reusable modules
- Software applications (apps) supporting different missions & payloads

Physical Modularity

- Expandable
- Add future capability
- Handle Supply Chain Risk Management and trusted hardware concerns

Open

- License free standards
- Full insight into workings to tailor
- Improved interchangeability

Networked

- Decouples software from physical location
- Packetized (easy translation) from one mode of transport layer to another
- Enables security auditing
- Provides a multiple layer security (MLS)foundation

As of yet, no one entity has brought all 4 of these efforts together in a single effort though it appears likely that the ORS is coming the closest with their follow-on efforts from the MSV. The SMC Science and Technology team will be encouraging the growth across all 4 fronts as pervasive technology investment portfolios for AFSPC capabilities. The most broad based way to obtain support is to encourage the use of IRAD funding to address these 4 fronts at the vehicle and payload levels and where there are still shortfalls, use the government research teams to close those remaining gaps.

GENERATING SHORT TERM WINS

Like small stepping stones used to cross a stream too wide to leap in one bound, or to build a bridge from one side of a chasm to the other, MONA leadership needs to generate short term and achievable milestones to allow the community to finish crossing the chasm. The team must provide solid foundations from which to launch the next step into the unknown. Due to the foresight and diligence of members of the research community, those initial stepping stones have been laid.

The AFRL Space Plug and Play Architecture validated the viability of composable systems. The ORS MSV validated the viability of MONA bus architectures for DoD space applications. The DARPA F6 Program validated MONA for inter-platform and payload interface applications with the ability to scale. The NASA Common instrument interface (CII) guidelines validated requirements for interfaces but left open the implementation of MONA modularity to ensure government did not over specify the desired end state. CII asks the community to take a different perspective than it traditionally did to the tight integration of instruments to their hosting platforms to explore the interface trade space. SUMO validated the approach to generate business cases for MONA and established a dialog for community wide change. By listening to the downsides AND upsides of various approaches, SUMO allowed a more realistic community interaction to play out. Instead of forcing a level of modularity that the systems engineers could execute if the customer REALLY think they want it, the idea has become what is the right approach that would also be championed by the program management leadership as the more affordable and resilient capability the customer REALLY needs.

Finally and most recently, SNAP validated that AIT business cases will close and industry can build on the SUMO approach to dialog and call out where the benefits are in exercising the paradigm. Industry can look at the first implementation of MONA that SMC has been aiming for (the SMC Chief Scientist has stated publicly) and everyone should be developing: Hosted Payload approaches to meet DoD needs. SNAP showcased achievable costs savings enabled by standardization which further reduced testing timelines for hosted payloads. Hosted payloads WILL be on RFPs. So what better of a time to prepare industry for that type of competition? What better time to engage the small satellite community to show where the next key stepping stones can be laid?

CONSOLIDATING GAINS AND PRODUCING MORE CHANGE: BUILD INDUSTRY MOMENTUM

Technologies and more importantly products for MONA are becoming available and the list is growing. Boeing Phantom Phoenix and NG Eagle M and Eagle S (ESPA) are key examples. Lockheed Martin is updating their A 2100 bus with more MONA like options for their customers. A recent RFI from the SMC Chief Scientist on standardized interfaces revealed that the majority of industry can and is interested in offering “standardized” but not “standard” products. So a single bus for all missions is not acceptable but standardized interfaces can be.

The industry gave examples of how MONA could be done and what the conditions for success would be. Industry is beginning to see cost savings and competitive advantages emerging with a MONA or similar approaches. How was industry able to arrive at this answer? Investments in space craft emulators and flat sats allowed industry to explore the ideas with minimal capital outlay. This is a natural off shoot of industry leveraging its own capital investments which comingle hardware and software in the loop options used to rapidly AIT new designs for the previous design paradigms . Almost all major primes have flat sat capability which can take immediate advantage of the MONA paradigms—industry can check to see if MONA makes sense and they can do it with very little NRE. They are doing the homework and coming up with similar answers. So what is the next stepping stone? Where must more change occur to keep MONA alive?

There are currently 2 major technology shortfalls that industry alone may find difficult to close themselves and this is were the focus of change must be. One of those shortfalls was simply bypassed during the SNAP demo and the other was beyond the fiscal resources of the SNAP team. The first shortfall that was bypassed was the key to modular physical interfaces, the thermal balance problem. It has been clear, all the way back to AFRL SPA, that the thermal issues at the interfaces, especially the payload to bus interfaces is the key remaining unsolved element of the standardized interface.

Several approaches have been tried for dealing with the thermal balance and as yet, it is still an art more than a science. On the Commercially Hosted Infrared Payload (CHIRP) effort, the thermal issue required millions of dollars in additional work to handle the thermal loads which affect the sensing payloads capability—and that problem was solved only for that specific payload on one specific commercial host.

The second major shortfall which is beyond current resources is how to handle the security concerns of using an open system. The problem comes with many names and forms, including advanced encryption and cyber resilience and cyber security solutions, but whatever it is called it requires a broad community to help solve the problem. It is likely a defense in depth problem with allowance for imperfection. The best we can hope to do is to operate through what will be a contested situation.

SMC Chief Scientist is actively working to frame the necessary technology needs and build collaborations to find workable solutions for these two problems. The immediate benefactor will be the HPO/HPIU programs as the most compelling and viable next procurements from the SMC product center perspective.

ANCHORING NEW APPROACHES IN THE CULTURE: THE SMALL SATELLITE CONTRIBUTION

It is now time to inject the power and innovation skills of the small satellite community into the MONA framework for change. Small satellite builders must join in the CSIS as it builds the consensus standards. The small satellite community can take the Figure 1 approach and agree to adapt it for their use with very minor modifications. It may even be possible for the small satellite community to lead the consensus building on the data and software architecture due to the investments in the MONA technologies. With far less capital investment inertia to overcome, the smaller satellite community can take the first agile steps to fully conquer the four “fronts” at the smaller scale. It is likely the small satellite community will have found an approach that can scale to the larger spacecraft designs or larger constellation approaches, due to the nature of the crossflow that has always existed at the engineering layer in spacecraft art. Engineers from smaller programs eventually become engineers on the bigger programs. They take with them the art learned at the smaller scale.

The small satellite community is in a very unique position to continue technology infusion particularly building a library of MONA applications (APPS) on the highest layer of the architecture stack. University curricula allow for the small design projects well suited to the APPS approaches and design coursework of seniors and graduate students. Small form factor engineering will continue to be at the forefront of tech demos, and flight demos due to the inherent perception of risk and risk aversion found in the larger programs.

Small form factor approaches must target operational on-ramps—the key near term mission area for applications will be the terrestrial weather monitoring missions which need to be recapitalized as the USAF finishes launching the last of the legacy meteorological support spacecraft. Small and cubesat form factors are emerging as key players in the environmental sensing area so will have a natural need to address the issues of environmental standards to which to test and qualify.

In addition, MONA like applications for space situation awareness could help spread the heavy infrastructure development and deployment costs which add billions in cost to the portfolio to enable the rest of the space craft to have situation awareness so as to be resilient to threats.

Above all small satellite contributions give industry ample time to prepare to compete and then encourage the MONA implementations. SMC is aware that industry cannot turn on a dime and both human and machine capital take time to develop. The MONA framework assumes a 5-10 year spin up time for industry to prepare for MONA capabilities.

CONCLUSION AND FUTURE WORK

This paper described a framework for bringing about critically needed change to the NSS enterprise architecture. This paper outlined the benefits and characteristics of a MONA framework, with a focus on the software architecture that enables MONA. The paper highlighted the resources available, process of implementation, and lessons learned from the SNAP demonstration and implementation. Finally, the paper presented ways in which the small satellite community can participate in the technology development and risk reduction necessary to mature this technology for spaceflight systems. In the future, the ability to enable new markets, lower the cost of doing business and align the SMC procurement portfolio to Better Buying Power 2.0 will pay dividends for all stakeholders in the space community.

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