The Dual-Radar Software Development Facility As A Case Study Of Interoperability

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Abstract

The Dual-radar Software Development Facility Project is an example of the collaborative efforts required between an Air Force System Program Office, a Air Force Logistics Center, the Air Force Research Laboratory, the Air Force Special Operations Command, The Contractor Raytheon, and the Contractor Boeing to provide a common (inter-operable) embedded information support environment for multiple weapon systems. This paper will provide a case study of the multiple programs (along with their associated histories) leading up to the realization of the Dual-radar Software Development Facility.

The Dual-radar Software Development Facility supports the radar software for both F-15 APG-70 and AC-130U Gunship APQ-180 Radars. The provision of a common support environment was proven feasible because the APQ-180 radar is a derivative radar of the APG-70, with several common components. The DrSDF program followed the Advanced Avionics Multi-Radar Software Support System (I & II) that first provided a feasibility study, and then provided the preliminary engineering designs for the DrSDF.

The Aerospace Command and Control and Intelligence, Surveillance, and Reconnaissance (C2ISR) Campaign Plan 2000 has a focus area called ISR Sensors and Platforms: The focus area states we need to invest in Global Air Traffic Management/Global Air Navigation System (GATM/GANS) for selected C2ISR platforms to sustain and modernize the fleet. This investment enhances our ability to meet the high demand for this capability throughout multiple Areas Of Responsibility (AORs). We need to deliver an effective and affordable ISR force mix fielding plan. This plan must determine the sensors and platforms required for achieving an optimum sensor mix and savings in concert with Intelligence, Surveillance, and Reconnaissance (ISR) Tasking Processing Exploitation and Dissemination (TPEDS) Focus Area.

This paper will provide valuable lessons learned through its history of providing a capability to support multiple radar sensor platforms. These lessons come from: (1) the

program’s early feasibility study, (2) the assembling of multiple disciplined integrated product teams, (3) the collaborative engineering that occurred between the 5 member engineering organizations, and (4) the ultimate multiple of platform support capability that DrSDF will provide. The paper will also show how these lessons will provide insight in providing the Air Force an effective and affordable ISR force mix fielding plan.

1. Focus Area: ISR Sensors And Platforms

The ISR Sensors and Platform issue is what are the appropriate investments in Air Force owned and non-Air Force owned capabilities, with emphasis on Theater Air Surveillance, Theater Ballistic Missile Defense, and Ground Target Surveillance to support real-time targeting and execution of the air war? The factors affecting this issue are:

- ISR assets are in high demand; coverage is required throughout multiple AORs
- Allied Force Lessons Learned stress the need to support the JFACC’s real time precision targeting requirements
- Rapid and accurate surveillance needed to support early engagement
- Dynamic sensor tasking required for time critical targeting

The consequences (without an integrated ISR investment strategy**)** related to Sensors and Platforms are:

- There will be insufficient ISR assets to meet demands, resulting in high op tempo and degraded ISR capabilities
- DoD will continue to invest limited ISR dollars in stove-piped solutions
- The Air Force will continue to have difficulty identifying and striking time critical targets (The CSAF's guidance to focus on time critical targets will not be met)

This excerpt is from the United States Air Force Aerospace Command Control Intelligence Reconnaissance (C2ISR) Campaign Plan 2000 [2].

2. Airborne ISR Sensors And Platforms Require Complex Infosphere Development Environments

Recently, a major factor in providing sufficient ISR assets was the Software Development Facility (SDF). The SDF allowed complex sensor systems to be fine-tuned and upgraded to address (or better address) the constantly changing threats found throughout the world. The main drawback to the SDF approach is that they are primarily dedicated to specific complex sensors and weapon platforms, requiring costly investments in overhead support equipment and highly skilled people.

3. AAMRSSS and DrSDF, A Case Study of Interoperability

The Software Development Facility (SDF) has evolved as a sophisticated environment to develop and maintain complex weapon system embedded software. The SDF not only must provide the tools, methodologies, and processes, but also sophisticated simulations and emulation of the system under test and its real time environment, plus a means to record, replicate, operate, and analyze the embedded system software. On an individual system basis, the provision of an SDF is expensive. Because of this expense, it would make sense to jointly utilize SDFs that could be adapted to support two or more dedicated software embedded systems.

The idea of using a common support environment to develop, maintain, and test weapon system embedded information is not new. When there is a downsizing of weapon system fleets, a deactivation of support facilities, or an introduction of a new system or subsystems. There often follows a re-examination of the support assets and how those assets can best be utilized or supplemented to give the necessary service wide (or DOD wide) life-cycle support. This re-examination often makes suggestions on how assets could be jointly used to provide the necessary support of the targeted weapon systems. It is from these re-examinations, that a much more detailed study has to be made in order to assess the feasibility of going to a common support environment. This study actually compares every component, function, process, and politic for a high degree of commonality. A serious mismatch of any one of these parameters could easily disqualify a common venture.

It should be clear by now that the most successful attempts for common support are those that are designed to be so from the beginning. Weapon systems or subsystems that are close variants of each other and based on high commonality of components and functionality are best candidates for common support. Better yet, is a holistic design, which extends to the weapon system's overall life-cycle and includes the support environment as well as links to closely related systems and subsystems. It is rare that multiple, fielded weapon systems can share a support environment. This is because, they have developed their own special support requirements, and their configuration management has evolved around different circumstances. Later on in this paper, a multiple fielded weapon system program called Advanced Avionics Multi-Radar Software Support System (AAMRSSS) will be presented which is successful. AAMRSSS' main reason for success is that the two Radar Operational Flight Programs it will support are derivative Hughes Radars, the APG-70 and the APQ-180, which will be jointly supported in the Warner Robins Air Force Base's F-15 Radar Software Development Facility (SDF).

Concurrency of common resources is a critical issue when investing in a multiple support environment. The decision to implement a common support environment is heavily based on the cost savings from using common resources. If the commonality is not managed and maintained, the strains of reconfiguring between weapon system's upgrades could compromise the efficiency of the support environment. This multi-configuration management requirement imposes an additional support cost on the weapon systems, which must be considered during requirement's analysis and reviewed throughout the systems lifecycles.

System obsolescence is a growing concern amongst weapon system maintainers. As the age of the weapon system and its sub-systems increases, the demand for spare parts, creative substitutes, and replacement becomes increasingly critical. This is not only true for the weapon system and its sub-systems, but for its support environment and the methods and processes involved in keeping it current. A multiple support environment can take advantage of resolving these critical obsolescence situations for the common components, but also absorb the costs of the multiple weapon systems peculiar component aging and shortage.

The expansion of the software development facility to handle additional workload impacts the priority of the individual weapon systems as well. How much is too much? What is the support saturation of the facility? Are there additional feasibility issues that must be addressed before proceeding with expansion? The conditions and resources that made a shared facility possible at one point, could very well change. Expansion feasibility studies should become a common practice of the shared facility.

The degree of test coverage for each of the weapon systems is an important aspect of the shared facility. This determines the allocation of the common testing resources, as well as their priority, and defines the unique testing resources for the individual weapon system's unique characteristics.

During the feasibility study phase, a have-to-have analysis should be performed. That is, what does each weapon system have to have, in order to be properly supported by the shared facility. For weapon system software support, this will include a software maintenance environment as well as the simulation and testing resources needed to exercise the software as robustly as possible.

The weapon system software maintainers are highly skilled, but also highly specialized scientists and engineers. As the common facility expands, the ability to utilize evolving technology and to stay technically current must be provided to these maintainers. Overlapping skills for multiple weapon systems, as well as system peculiar skills must be added, exercised, and evaluated against the full capability of the shared support environment.

Where a peculiar requirement (or skill) is implemented (or modified), it will have an impact on the overall support capability. Expanded functionality for one weapon system will require additional resources of some type. The overall capacity to provide these resources will have to be addressed.

Floor space is a constant concern, when more than one entity is concerned. How many squares are available? A good floor plan, ample heating-cooling, and power provisions are factors to frequently review.

2.1 Advanced Avionics Multi- Radar Software Support Study (AAMRSSS)

The first phase of the Advanced Avionics Multi-Radar Software Support Study (AAMRSSS) studied the feasibility of using a common Software Development Facility (SDF) to support multiple software system platforms, specifically the F-15 Eagle and the AC-130U Gunship. The APG-70 Radar in the F-15 Eagle and the APQ-180 Radar in the

AC-130U Gunship have a high degree of LRU commonality despite the different missions of their respective weapons systems. The time critical natures of these radars and their diverse functionality have been addressed in this Air Force sponsored study with Raytheon Aircraft Company. Additionally, through the separate sponsorship of the Gunship SPO, Rockwell North American (now Boeing) participated in the study reviews as the prime contractor for the AC-130U Gunship. Through this study, an approach was developed to leverage a common OFP support facility for both radars. Key issues included: differences in the missions of the weapons systems, the aircraft performance, the radar modes, and the avionics suite; and the nature of the radar environment and real-time radar return data generation. This section summarizes the issues encountered in the study's investigation, and the features of both the radars and the support needs that have influenced the design of a shared OFP support environment.

The F-15 Eagle weapon system, with the APG-70 Radar has been operationally deployed much earlier than the Gunship with an APQ-180 radar, and had already implemented an APG-70 SDF. This facility provides capabilities for systems/software analysis, software development, and system integration and test. These capabilities are supported by three major subsystems: the Central Development Facility (CDF), the system test benches (ASB and 70RTBS), and the Instrumentation Data Reduction and Analysis System (IDRAS). Figure 1 illustrates these subsystems and their associated capabilities.

The proposal to share a common support environment between the F-15 APG-70 and the Gunship APQ-180 derives benefits from a common architectural heritage. Figure 2 illustrates the Line Replaceable Units (LRU) of the Gunship APQ-180 radar. Common processes, methods, and tools were utilized in the development of the F-15 APG-70 Radar and the Gunship Radar. Both radars utilize common processors (radar signal processors and radar data processors) that utilize Mil- Std-1750A instruction set architectures for data processing and control functions. With the minor exception of OFP built executives, the CDF and IDRAS support areas that can be used in common across both

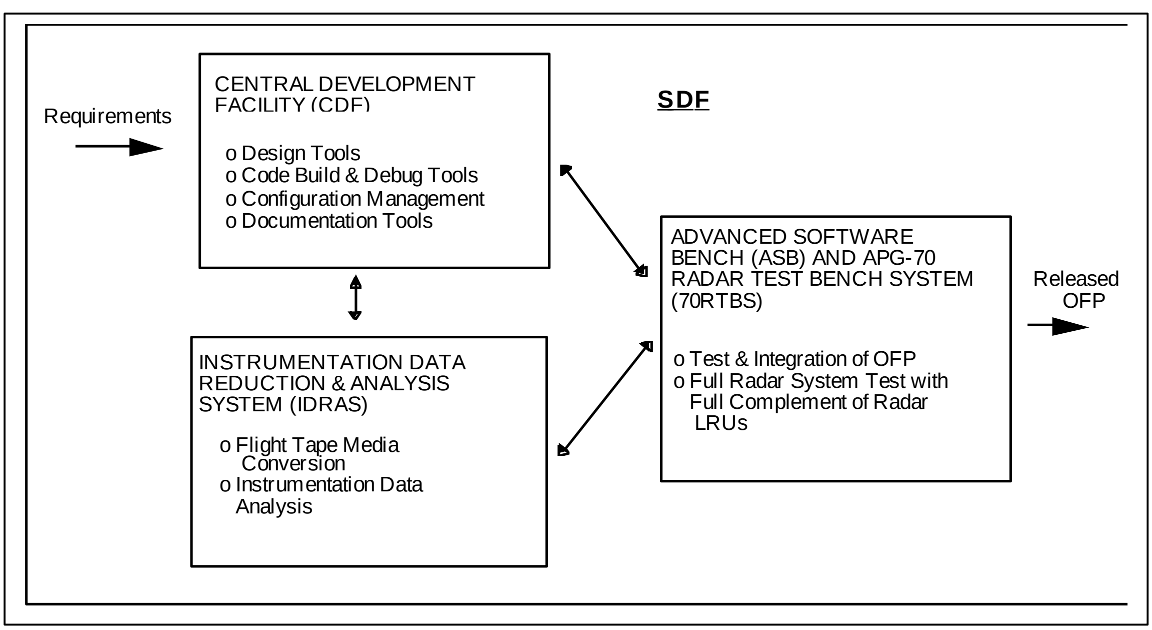

Figure 2 – Line Replaceable Unit Components of the AC-130U Gunship' Radar

application systems. The primary area impacted by the proposed multi-platform support environment is that of the system test benches.

The system test benches are significantly impacted by the application specific requirements of the supported platform's mission and system interfaces of the avionics to be supported. Environment and ownship simulations used in the system test benches, as well as test equipment interfaces are affected by this application specific requirements. Figure 3 illustrates and summarizes the system test support components that have been addressed in the system test support of the APG-70 and APQ-180 Radars.

Cost-effective weapons systems support is critical in the current fiscal environment, and has been a key concern in the deployment of the AC-130U Gunship. Since the Gunship's APQ-180 Radar uses the same processor suite and OFP architecture as the F-15 Eagle's APG-70 Radar, an attractive opportunity exists to reduce cost by leveraging support systems. Basic radar support requirements are well understood at this time and a multi-platform support environment approach has been identified as an important strategy.

Improvements in the test capabilities for the air-to-ground radar modes critical to the Gunship mission, as well as the extension of automated test capabilities to improve test bench utilization, became the focus of second phase study efforts (AAMRSSS2).

Three test support areas were identified for improvement of the fidelity of air-to-ground test of the radar OFP: the Analog Target Generator (ATG), the Digital Target Generator (DTG), and a Digital Play Back System (DPBS). The target generators (i.e., ATG & DTG) are SDF test support products that are to be upgraded for support of the Gunship modes. The playback system (DPBS) is a new capability leveraging current SDF assets

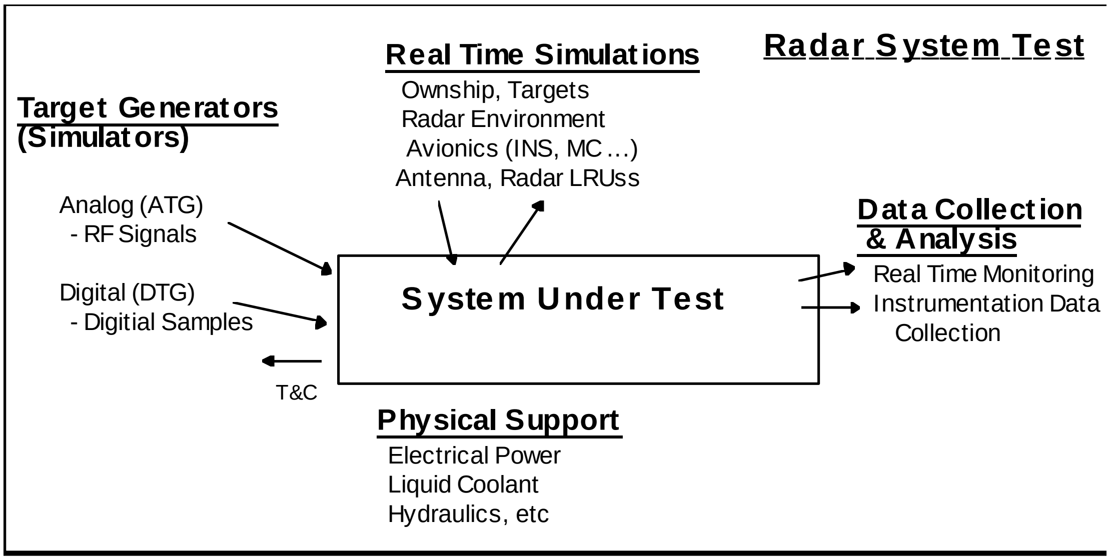

Figure 3 – DrSDF System Under Test

to provide for the playback of instrumented flight data into the processors of the radar test bench.

The ATG provides RF signals to the radar front-end to simulate various radar target scenarios. Technology improvements in the ATG are driven by the radar's High Resolution Map (HRM) and Ground Moving Target Track (GMTT) requirements for much improved update rates and enhanced mainlobe clutter modeling.

The DTG provides digital radar return samples (i.e., I/Q data) to the radar signal processor as they would be sent by the radar front-end. Technology improvements to the DTG provide enhanced ground return simulation with clutter modeling based on simple terrain surfaces.

Target generators as used in the SDF are based on simulation models that have limited fidelity with respect to the complexities of the real world. In general, these models allow the performance of the OFP and the radar to be validated against their design models. However, validation of the model design itself is limited. The DPBS extends the test capabilities of the SDF radar test bench to validate mode design against full fidelity real world conditions, by providing the ability to use instrumented flight data. This capability allows the SDF to support the Gunship APQ-180 testing with a pre-recorded suite of missions, as well as the ability to exhaustively investigate new conditions.

Automated test is currently supported on the SDF radar test benches through the use of the Automated Verification & Test System (AVTS), a scripted test system that is layered on top of the GUI's of the test bench. Extensions to the AVTS enabling support of the Gunship were evaluated and planned to improve the shared utilization of the SDF. Notable other improvements to support the Gunship included the incorporation of the Gunship battle management controls and automated access to display imagery [3-11].

2.2 The Dual Radar Software Development Facility (DR SDF)

The multi-use, multi-platform support facility defined by the AAMRSS Studies and subsequently developed under an IPT composed of the AC-130U Gunship SPO, Air Force Special Operations Command (AFSOC), Warner Robins Air Logistics Center (WR-ALC), Air Force Research Lab and the Raytheon contractor; is known as the Dual Radar Software Development Facility (DR SDF). This facility leverages the capabilities of the existing F-15 SDF at WR-ALC and integrates the necessary enhancements to provide effective support of both the F-15 Eagle APG-70 radar and the AC-130U Gunship APQ-180 radar.

The DR SDF development program is currently on-going and is also providing parallel support to an on-going Boeing/Raytheon APQ-180 radar upgrade program. DR SDF test support products described earlier under the AAMRSSS discussion are being used to assist in the current radar upgrade. In addition, a Digital Instrumentation System (DIS) is being integrated into the AC-130U Gunship to provide full bandwidth collection of baseline flight instrumentation data as well as developmental flight test data. The DIS provides for full bandwidth digitized radar return data for performance analysis of the Gunship air-to-ground radar modes, as well as instrumentation of associated avionics I/O data. This data will also be available for later use with the DPBS previously described.

3. The Joint Battlespace Infosphere

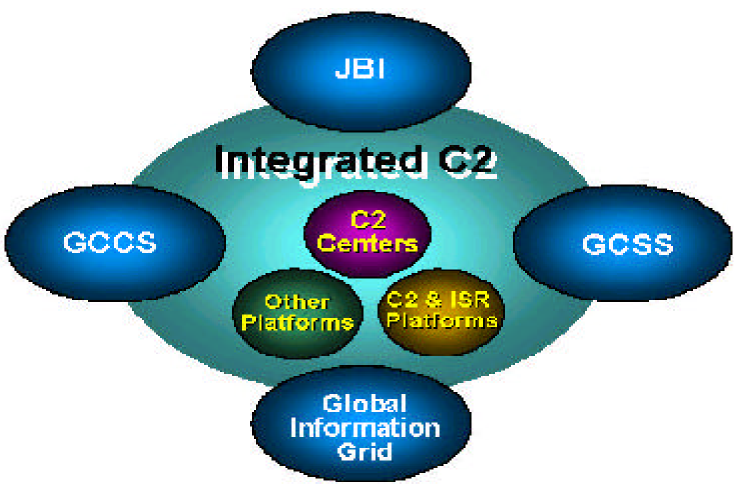

Figure 4 – The JBI Domain

The executive summary of the United States Air Force Scientific Advisory Board Report on "Building the Joint Battlespace Infosphere" [1] defines the Joint Battlespace Infosphere (JBI) is a combat information management system that provides individual users with the specific information required for their functional responsibilities during crisis or conflict. The JBI integrates data from a wide variety of sources, aggregates this information, and distributes the information in the appropriate form and level of detail to users at all echelons. The JBI was originally described in the 1998 USAF Scientific

Advisory Board (SAB) report *Information Management to Support the Warrior*. At the joint task force (JTF) commander's level, the JBI is a powerful command and control (C^2) system that combines inputs from a variety of sources, including existing C^2 systems, reconnaissance data, satellite data, unit capability data, logistics data, and real-time battlefield conditions. The JBI builds an aggregated picture from these combined inputs, giving unparalleled situational awareness accessed as easily as a web page. The JBI also provides for speedy downward flow of information, so when commanders order an action, the action is received and implemented at the subordinate level almost immediately. The commander in chief (CINC) or JTF commander creates a JBI for a specific purpose, usually in response to a crisis or conflict. The JBI enables the commander to focus information support for a specific operational purpose, ensure or limit access to critical information, and provide an information management system that can respond to natural or enemy actions that disrupt communications capabilities. As units are assigned to the mission, their information needs are electronically identified, and available information is automatically accessed. Thus, deployed units are ready to fight immediately upon being deployed or assigned [1].

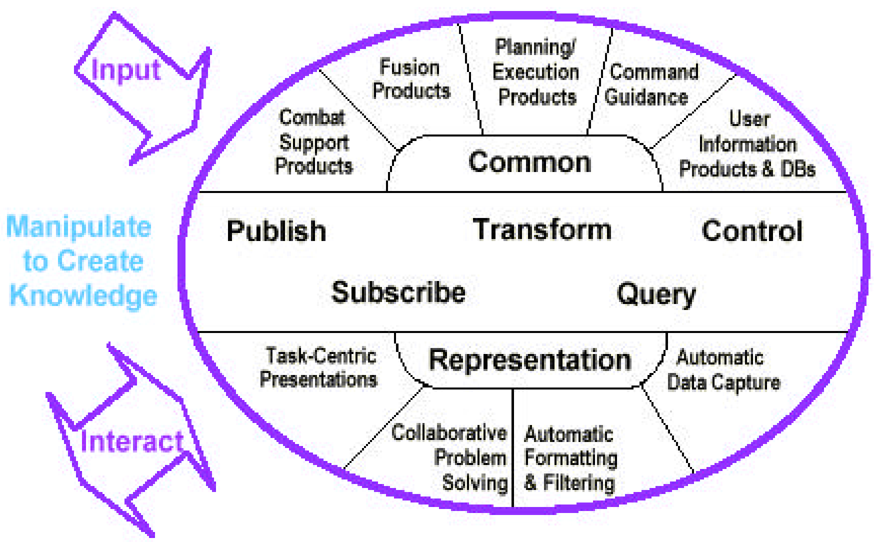

Figure 5 – JBI Capabilities

Supporting these capabilities and forming a foundation of the JBI is a platform of protocols, processes, and common core functions that permit participating applications and organizations to share and exchange critical mission information in a timely manner. It provides uniform rules for publishing new and updated objects into the JBI and promptly alerts any JBI clients that have subscribed to such objects. These properties enable dynamic information flows among client programs of the JBI, serving to integrate the clients to conduct a single mission. The JBI platform integrates many individual information systems that currently support operational forces. Each existing system has been developed in a stove-piped fashion; few interoperate with each other. The JBI acts as an intermediary between these systems, converting information from one representation to another to enable interoperability. In addition to acting as middleman between disparate systems, the JBI interprets the information flowing between applications, using it to build its own, more complete, picture of the current situation. Furthermore, the JBI tailors this picture for individual users: the commander gets a high-level view of the campaign, while the soldier in the field gets a detailed description of a nearby hostile base. The JBI provides an architecture for the incorporation of future data capture technologies that exploit better sensors, databases, fusion engines, automated analysis tools, collaborative planning and execution aides, and distribution controls. It is also a disciplined process that guides the activities of people responsible for obtaining, verifying, fusing, presenting, analyzing, and controlling the information necessary for success in any operation [1].

The JBI is connected to, and interoperable with, a variety of existing and planned C^2 and combat support information systems. The JBI is not intended to replace C^2 systems, but to be the substrate for integrating them. The JBI subscribes to pertinent information published by supporting systems and, when necessary, pulls specific information from other networks. In addition, the JBI connects to fusion engines and may perform fusion on its own, thereby ensuring that the most complete and coherent picture of the battlefield situation resides within the JBI itself. The JBI concept recognizes that display technology is constantly advancing and that new displays must be tailored for users from flight leader to JTF commander. The JBI provides services through a federation of multiple servers. The Global Information Grid connects these servers to each other and to the many systems that support the JBI. Many of the servers provide services from the rear via reachback, thereby limiting the forward footprint of the JBI [1].

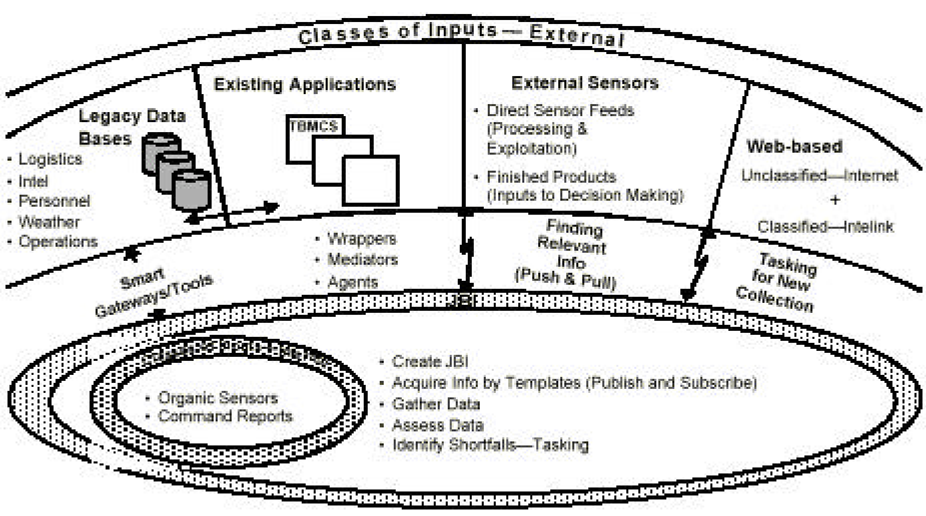

Figure 6 – JBI Architecture

4. Summary and Conclusions

The consequences (without an integrated ISR investment strategy) related to Sensors and Platforms are:

- There will be insufficient ISR assets to meet demands, resulting in high op tempo and degraded ISR capabilities
- DoD will continue to invest limited ISR dollars in stove-piped solutions
- The Air Force will continue to have difficulty identifying and striking time critical targets (The CSAF's guidance to focus on time critical targets will not be met)

A way to provide sufficient ISR assets is to take advantage of those assets that have similar support environments. It has been estimated that 75% of a weapon system's (including ISR assets) lifecycle costs is that of support. Leveraging multiple-support platforms increases the assets available.

Another name for stove-piped solutions is a band-aide approach. Both stove-piped and band-aide approaches to ISR platforms come from the mentality of making due. Fly the system, and fix it when it breaks. Leveraging multiple assets gives each asset the benefit of the other, and allows the combined assets to place an emphasis on pre-emptive life-cycle issue.

The use of a multiple platform support environment brings together domain experts from different area. The combination of these skills might provide the opportunity to address time critical targets from a different and fresh perspective.

The lessons learned from the Dual Radar Software Support Facility (DrSDF) program and it predecessor programs (Advanced Avionics Multi-Radar Software Support System I & II) guide the way for providing similar support to C2ISR assets. These programs provide rich lessons in leveraging commonality, designing for commonality, and in multiple organization engineering (collaborative engineering) efforts.

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