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Open System Design and Evolutionary Acquisition Application To The National Missile Defense Family of Radars

Orazio A. Di Marca (USAF/ESC), Stephen B. Rejto (MIT/LL), LCDR Thomas Gomez (BMDO)

Abstract

The traditional acquisition process is complex and lengthy. The process does not allow appropriate user interaction/feedback and often, due to its extended period of performance, continuity in program office personnel is lost. Developments usually experience schedule slips and cost over runs.

Traditional acquisitions usually develop closed (stove piped) systems employing "custom" component with "tightly coupled" software and hardware. The developments lack open system architectures and have minimal commonality, standard interfaces, and protocols. The systems when fielded, usually, are outdated and become obsolete. They are difficult to operate and frequently are surpassed by current technology. They do not easily allow state-of-the-art technology insertion and use of the latest Commercial-Off-The-Shelf (COTS) equipment. Progressively, they become more expensive to maintain.

Acquisition reforms have introduced new innovative approaches to systems procurements. Open System (OS) design methodology and the Evolutionary Acquisition (EA) implementation of the spiral process offer a framework for achieving a shorter acquisition timeline, ability to leverage COTS, improve weapon systems performance, allow technology "refresh", and lowers the overall life cycle costs.

Federally Funded Research & Development Centers (FFRDCs) have used an open system approach in their radar developments. Transitioning their technology design methodology to industry will reduce acquisition and life cycle costs. More importantly, it would allow leveraging of industry's rapid advances in commercial technological development. It will also facilitate system upgrades to keep up with the evolving threats.

Introduction

Due to a variety of reasons, defense firms have lagged behind in leveraging FFRDC's technological innovations and Department of Defense (DoD) acquisition reforms to improve and shorten the development timelines. Figure 1 illustrates the history of sophisticated high power radar developments since the late sixties. The figure depicts frequency of operation and the approximate timeframe the radars were developed by both FFRDCs and industry. It also groups radar systems that are related in their system functions. A close inspection of the figure shows that radars are grouped in a specific "family" of radars that operate both at narrow and wide bandwidths. Note that the X-Band family of radars is not isolated only to the GBR system and its previous prototype developments, rather the family of radars include systems with wideband and imaging capability: the Haystack radar, HAX, MMW, COBRA DANE, COBRA JUDY S-Band, COBRA JUDY X-Band, HAVE STARE, THAAD, COBRA GEMINI, and the recent prototype Ground Based Radar (GBR-P) situated at the Kwajalein missile range. Furthermore, the figure also illustrates the limited transfer of technology from one development to another, and potential capability for future transfer of technology from one system to another as improvements and technology advances are made.

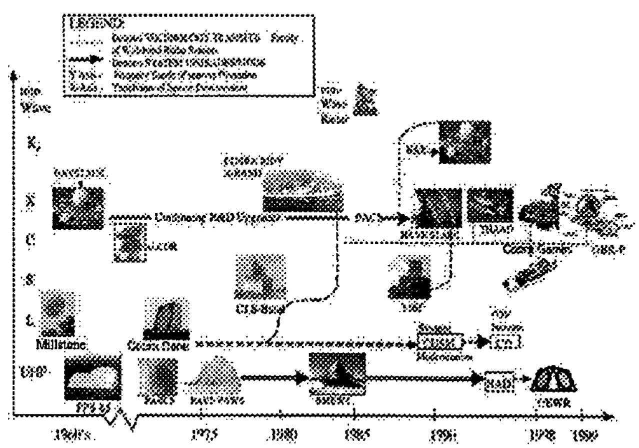

Figure 1. High Power Radars

A number of efforts have addressed means of overcoming the high cost drivers in the design and development and modification of these highly complex,

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high power surveillance, threat warning, tactical and range instrumentation radar systems. These drivers include, but are not limited to, complexity of radar designs; stove-pipe designs; lack of competition; use of different programming languages; non-standardization of hardware components; interface incompatibilities; quality of workmanship; pushing the "state-of-the-art"; design changes; multi-mission capabilities; operation in harsh climates; etc. Figure 2 illustrates the similar functions yet some incompatibility of both hardware and software of several representative current radar system designs.

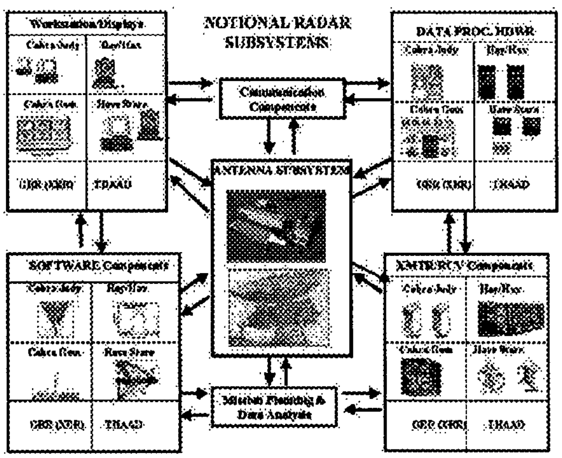

FIGURE 2 – Notional Radar Incompatible Subsystems performing similar functions

Although the representative radar subsystems perform the same functionality, different components are used with minimal regard to interfaces, commonality and standardization.

Limitation of NMD Existing Radar Designs

Current NMD radar designs and other defense establishment developed systems do not have an open architecture as defined by the Office of the Secretary of Defense, Joint Task Force on Open Systems. Designs lack standardization and commonality between radar systems, lack standard interfaces, incorporate minimal amount of COTS and maximize use of "custom" components. Both hardware and software are "tightly" coupled making future modifications/upgrade complex, lengthy, and costly. As a result, upgrades can only be done, successfully, by the original developer.

Open Systems (OS)

OS design decomposes a system in a distributed, loosely coupled, subsystem "open" architecture, characterizing and defining all subsystems, interfaces, and protocols. In today's environment of rapid advances in technology, signal processing, and manufacturing, open systems design is the best design solution in reducing life cycle costs. The OSD Open System Joint Task Force has a web page, http:/www.acq.osd.mil/osjtf, that offers a tutorial in the Open System design approach. Figure 3 depicts the historical DoD development cycle taking 8-15 years to design, develop and deploy a major system as compared to the commercial market that develops new technology 4 to 8 times faster. Due to commercial market dynamics, supporting technology is constantly evolving at approximately 18 month cycles. An open system architecture allows this new technology to be inserted with minimal impact to the system's operation.

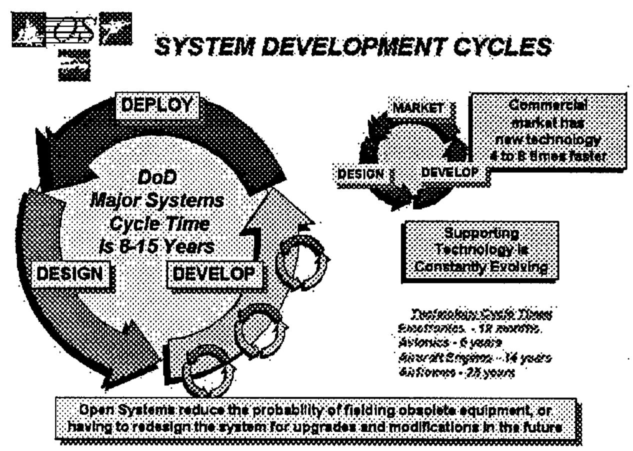

FIGURE 3 – System Development Cycles

Figure 4 depicts the open system design methodology. Open Systems facilitates using up-to-date technology in DoD Weapon Systems, even if the supporting technology changes at a rapid rate. An open system is a collection of interacting components designed to satisfy stated needs. All components conform to formal interface specifications. Interactions among the components depend on the interface specifications; in particular, the interface specification of all components in an open system is

- Fully defined,
- Available to the public, and
- Maintained according to group consensus.

An open system approach

- Is an integrated technical and business strategy.
- Uses modular hardware and software design.
- Buys, rather than builds, individual components.

A key aspect of OS is a focus on decomposition and interfaces, which provides maximum flexibility in developing and maintaining a system. By decomposing a system into functional units that are connected using open interfaces, developers can select components from a competitive marketplace based on performance, quality, and price. Replacing older parts with new components that adhere to the standard interface provides a maintenance and upgrade solution that minimally impacts the rest of the system.

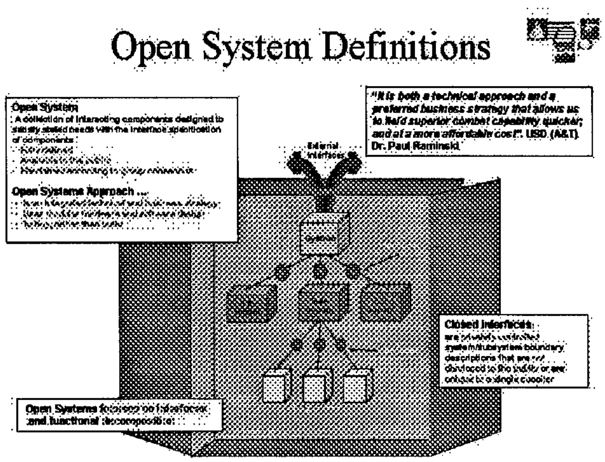

FIGURE 4 – Open Systems Design Methodology

A common example of an open system is the personal computer, which provides standard interfaces for disk drives, graphic cards, and other peripherals. By focusing on the interfaces, personal computers can be built using the best new low-cost technology. Customers also benefit by being able to replace or upgrade components independent of a specific vendor.

FFRDC Investments in Open System (OS) Developments

The MIT's Lincoln Laboratory (MIT/LL) has used open system design methodology in their state-of-the-art radar technology developments. This methodology has become known as the Radar Open Systems Architecture (ROSA). Ever since the development of the high power Haystack radar, the Laboratory has minimized "custom" components and maintained "open" radar designs, thereby, allowing continuous upgrading/modernizing using the latest COTS components, at minimal cost to its sponsors. The radars continuously get upgraded with the latest state-of-art technology. Systems are "refreshed" with COTS as advances in the commercial sector occur. By using an open design, leveraging COTS, and inserting new technology at the appropriate times, the radars, essentially, never become obsolete. Figure 5 and Figure 6 depict the ROSA design methodology.

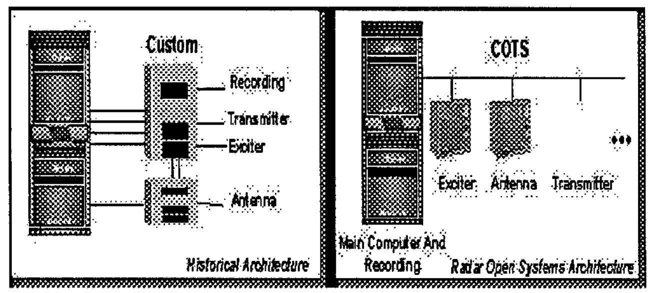

FIGURE 5 – Historical "Stovepipe" Design vs. ROSA

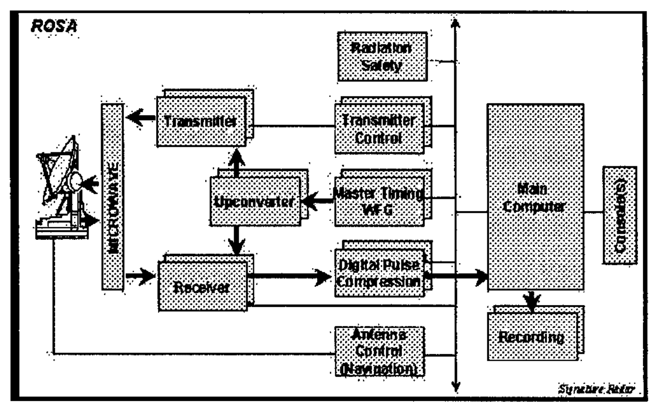

FIGURE 6 – ROSA System

The following design & development activities by the Laboratory in partnership with Government services demonstrate the feasibility of the ROSA design methodology:

Processing And Control System (PACS) Distributed Systems Implementation at Kwajelein

- The PACS system implemented a distributed (open) processing architecture that was utilized at the Kwajalein Discrimination System.

Haystack (X-Band)/Haystack (Ku-Band) Auxiliary Radar (HAX) (PACS upgrades)

- The distributed architecture, the PACS, was transitioned to the Haystack radar and its design methodology used in the development of the HAX radar.

COBRA GEMINI (S/X Bands) Development

- Prototype development of a high power, dual band, mobile radar, within 24 months, "ESC/MITRE/LL" team using a Radar Open System Architecture and maximum use of emerging technology and COTS components. Figure 7 depicts the COBRA Gemini development during testing at MIT/LL's Millstone Hill and sea-based application.

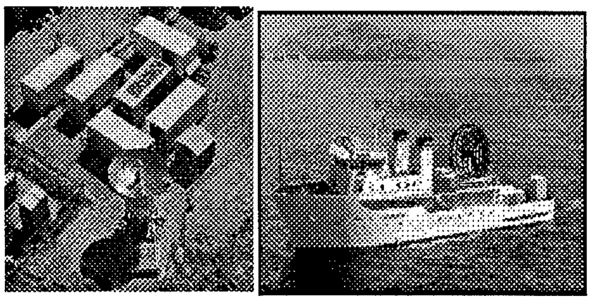

FIGURE 7 – COBRA GEMINI Prototype Dual Band Radar System

Kwajelein Modernization and Remoting Facility Upgrades

- Program funded by the Army to upgrade, insert new COTS technology, standardize and establish commonality for multiple radar facilities (ALCOR (C-Band), TRADEX (L/X-Bands), MMW (KA/W-Bands), ALTAIR (V/U-Bands)) using ROSA. Figure 8 depicts subsystems components utilizing COTS.

FIGURE 8 – KMR ALCOR subsystem Components

Haystack (X)/HAX (Ku)/Millstone (L) Upgrades

- AFSPC funded effort to upgrade, insert emerging COTS technology and establish commonality for the Haystack, the HAX, and Millstone radar facilities using ROSA. The OS architecture, available subsystems, and generic radar software have drastically reduced the cost for the modernization effort at Millstone Hill.

The above examples of the Radar Open System Architecture design methodology can and should be exploited in existing and new NMD designs. Transferring this design methodology to BMDO's NMD developments will assist NMD developers to migrate to an open system radar architecture.

Acquisition Reforms and the Evolutionary Acquisition (EA) Process

Many studies of past historical acquisitions and revised NMD cost estimates have shown that DoD weapon systems' cost continue to increase. The Evolutionary Acquisition (EA) process was implemented to attempt to reduce the acquisition costs and timelines for fielding a product.

EA is a nontraditional, overarching acquisition strategy whereby a core capability meeting a valid requirement is fielded with the intent to develop and field successive additional capabilities in spirals, as requirements are further defined, throughout the mission operational life of the system. EA offers a more rapid fielding of a solution to a customer's requirement even if only a partial solution. It also offers continuous improvement of the product and concept of operations toward a 100% solution through subsequent spiral cycles. Figure 9 illustrates the Spiral Process originally implemented at the Air Force's Electronic Systems Center (ESC) under the leadership of LTG Kadish.

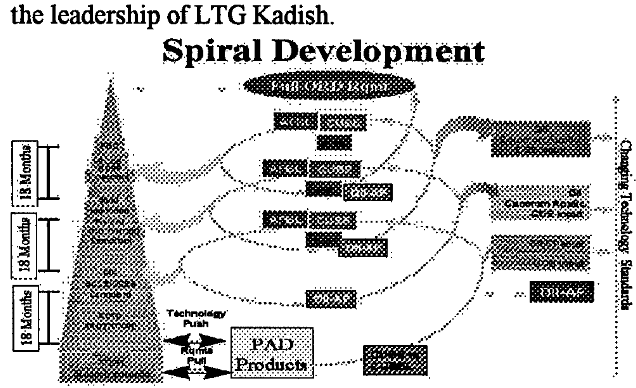

FIGURE 9 – Spiral Development Process

Spiral Development Application at ESC

The Spiral Development process and use of the Command & Control (C2) Unified Battlespace Environment (CUBE) at ESC for integrated testing and verification guided the SPOs in leading Integrated Product Teams (IPTs) to deliver the required C2 capability within the specified cost, schedule, and performance parameters in accordance with the standards defined by the Defense Information Infrastructure - Common Operating Environment (DII-COE) and the Joint Technical Architecture (JTA). The framework also provided the means for the SPOs to provide feedback for changes to the DII-COE and additional capabilities requirements for inclusion in future upgrades.

Command & Control acquisitions are ideal candidates for the EA process because the system requirements are difficult to quantify and they are expected to change as a function of scenario, mission, theater, and emerging technology. Spiral Development allows the necessary rapid system upgrades keeping in step with the evolving threat and emerging technology. Figure 10 illustrates a notional application of the Spiral process to the BMDO NMD architectures.

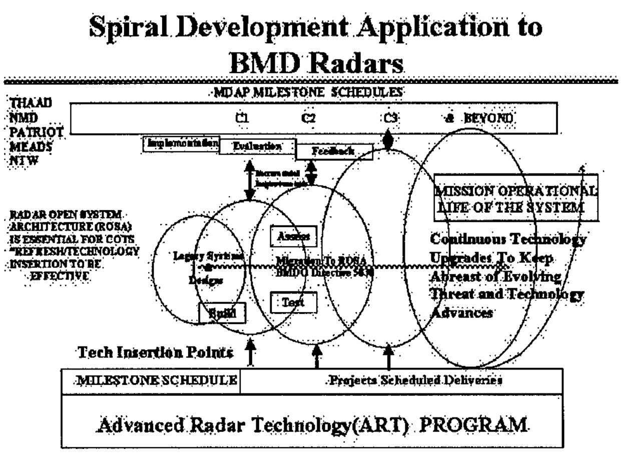

FIGURE 10 – Notional Spiral application to BMDO's NMD Architectures

The Spiral Process goes "hand-in-hand" with an Open system architecture. Without it, "technology" will be developed for "technology" sake with a small chance of being transitioned. Due to the large investment made in the present NMD designs, it becomes cost prohibitive to "force" an open system architecture on the existing NMD developments. However, a plan to migrate to an open system architecture is feasible and should be pursued. Without an open system architecture, technology that is currently being developed cannot easily be transitioned at the appropriate development completion dates.

Defense Information Infrastructure Common Operating Environment (DII COE)

The Defense Information Systems Agency (DISA) is the caretaker of the DII COE. The DII COE is Mission Application Independent. It is: an architecture; an approach; a collection of reusable software; a software infrastructure; a set of guidelines and standards. The software is developed in layers: the kernel; infrastructure services (data exchange) and common support applications. The mission applications work on top of the kernel, infrastructure services and common support applications.

Benefits to BMD Radars

Implementing the above design approaches offer open systems, commonality, interoperability, portability, supportability and affordability. These approaches refrain from using custom developments, proprietary hardware and software. The radar functionality is decomposed into building blocks using industry standard open system, commercial products and standard interfaces making future upgrades less complex and cost effective. Benefits can be summarized as follows:

•Reduced Total Cost of Ownership
- "Design-specific" independence enables future support and rapid upgrades.
- Enables flexibility and cost advantages of multiple sources of supply.

•Decreased development costs and schedule by leveraging commercial technology R&D, competition, test, and quality control
- Best lowest cost product vs. single in house product
- Purchase vs. specification, design, review, produce
- Warranty vs. test

•Enables spiral development process
- Can deploy latest technology available
- Ability to use technology insertion to meet evolving threat

Radar Open System Architecture (ROSA) Application to NMD Family of Radars (THAAD, GBR, UEWR)

Migration of current/potential NMD radar operational systems and designs to an open system architecture is feasible, cost effective, and can be performed in an evolutionary (spiral) fashion. As part of BMDO's Advanced Radar Technology program, migration of open system architecture to NMD systems is being investigated. The migration can be initiated by first, making an assessment of current designs by applying FFRDC developed tools (e.g. MITRE developed Model Reference Technology (MRT)) to decompose and characterize the systems. MRT is a tools-supported modeling and simulation technology process that enforces the disciplined use of models and simulation to solve project, management and system engineering problems. MRT is comprised of a tailorable process, a system engineering approach, and a federated set of tools.

MRT includes reverse engineering capability of legacy code and provides an integrated, system and technical view compatible with Joint C4ISR Architecture Planning/Analysis System (JCAPS). It permits drill down from requirements "shalls" to lines of code associated with its ("shall") implementation. It provides a birds eye view of the traffic flow (digital bits) within the system and helps to identify/define interfaces and use of protocols. It also assists in defining those "custom" areas in current NMD radar design that prevent the systems from being open. Once the appropriate identification and definition of all interfaces and protocols are made, a planning schedule can be developed to illustrate an evolutionary acquisition using spirals of development to migrate to a Radar Open System Architecture.

Figure 11 depicts the MRT process as applied to the COBRA GEMINI prototype development effort. Legacy Systems software source code was obtained and reverse engineered to identify low level architectural features. In combination with other MITRE and COTS reverse engineering tools, a design package was developed that served as a basis for follow-on software fabrication, training, and software maintenance.

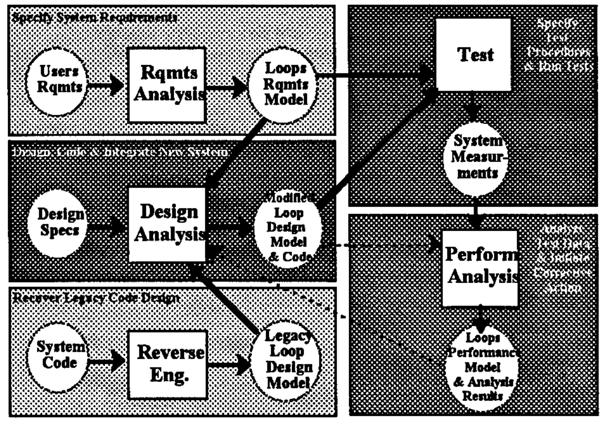

FIGURE 11 - Model Reference System Engineering Process

For BMDO NMD systems, the migration to a radar open system architecture can easily be demonstrated, cost effectively, by transitioning the FFRDC ROSA design methodology to the Theater High Altitude Area Defense (THAAD) User Operational Evaluation System (UOES) phased array radar. As reported by BMDO's POET future Radar Acquisition Roadmap Study Team (RARST), the THAAD UOES are becoming costly to maintain and unsupportable due to a variety of reasons. It was recommended that a potential solution was to migrate the radars to an open system architecture The same programmatic and design philosophy used in design and development of the COBRA GEMINI and other FFRDC legacy systems would be applied to the prototype design and development of THAAD UOES replacement subsystems. At completion of subsystem testing and integration by a team of Government, FFRDCs and industry, existing THAAD subsystems, with the exception of the phased array antenna, would be replaced with the newly developed ROSA compliant COTS equipment. Figure 12 illustrates a notional three phased approach in pursuing this course of action.,

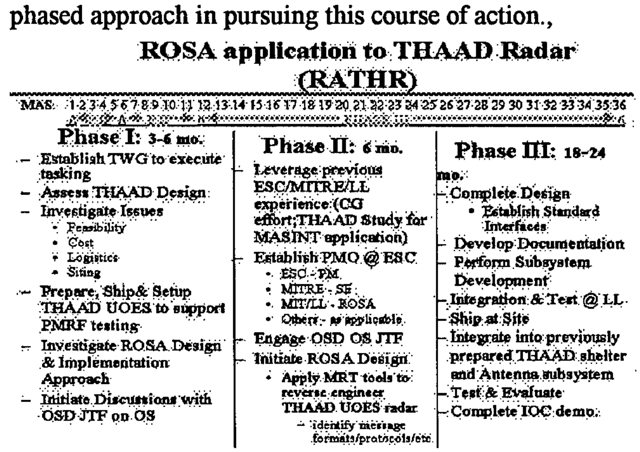

FIGURE 12 - Three Phase Approach to THAAD ROSA Migration

ROSA Potential Migration to Other Radar Developments (Ground-based, Sea-based, Airborne) and BMC3 NMD Architecture

Classes of radars consist of more than just the "Family of GBR radars", a term that we have heard so often. The radar field includes not only the "GBR" kind of systems, but it also includes airborne, surface based (land or sea) and space based. Implementation of open system design applies not only to the "GBR", but also to any other radar system design.

Since C2 acquisitions are ideal candidates for the EA process due to changing requirements as a function of scenario, mission, theater, and emerging technology, the BMC3 NMD architecture would benefit from an OS and an Evolutionary Acquisition approach.

Summary/Conclusion

The key to achieving competition, commonality, ease of COTS refresh, assure interoperability, lower O&M costs, software portability, lower life cycle costs, etc., is to implement Joint Technical Architecture (JTA) and Defense Information Infrastructure Common Operating Environment (DII COE), open system design, and standard interfaces and protocols. Where standards (both Government and Industry) do not exist, they need to be established. Open Systems provides a cost-efficient means to deploy new technology in existing sensors and new system developments. Open System design approach is "essential" and has to be made mandatory in any DoD system acquisition. The Standards Committee of the Institute of Electrical and Electronic Engineers (IEEE) and the OSD JTF on Open Systems, together with the support of industry, are the offices that could perform a detailed investigation and assessment, and ultimately, establish interface "standards" for the development of radar systems.

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7 June, 2000

MEMORANDUM FOR

Administrative Chair (Roger Medd)

FROM: Orazio Di Marca
USAF/ESC

SUBJECT: 9^{TH} Annual AIAA/BMDO Technology Conference Paper #9-7 Submittal

Attached is the final version of Paper #9-7, Open System Design and Evolutionary Acquisition Application to the National Missile Defense Family of Radars. If you have any questions I can be reached at Area code (781) 377-9453.

Orazio A. Di Marca

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