RASSP: Viewpoint from a Prime Developer

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Abstract

The Lockheed-led team of Motorola, Hughes and ISX has met all of the primary RASSP program objectives during the first year of the program. This paper reviews the goals of the program, and the unique ways in which Lockheed is meeting them. The flexible methodology and design environment are described along with the progress made in creating a standard enterprise framework. The progress of the demonstration effort is detailed as is the work towards proliferation of the RASSP process. The emphasis on VHDL and Ada-based virtual prototyping and its impact on Model Year Upgrades is discussed. The creation of the Virtual RASSP Corporation and the special Internet communication protocols developed to support the program are reviewed. The commercial spin-off of RASSP is discussed. Accomplishments in each of the program areas are reviewed along with specific goals for the next year of the program.

1.0 Introduction

While the full title of the RASSP program (Rapid Prototyping of Application Specific Signal Processors) is self-explanatory, several of the accompanying goals of the program required that Lockheed structure its RASSP program in ways that are unique. There are four primary objectives that must be met in RASSP. The first of these is the reduction of the length of time it takes to develop an embedded digital signal processor by a factor of four. Coupled to this is a goal of reducing the life cycle cost by four. In addition, the resulting product must exhibit what our team terms *unprecedented first pass quality*. For hardware and software to work together the first time requires the RASSP system make extensive use of the concepts of ***Virtual Prototyping*** and ***Model Year Upgrades***. These two concepts are discussed later in this paper and are explored in detail in two accompanying papers on the Lockheed ***Design Environment and Demonstration***.

There is one additional goal of the RASSP program which has had significant impact on the Lockheed program. The desire of the government to have RASSP produce a lasting impact on the way that digital design is done in the United States, has led to the formation by Lockheed of a ***Commercial Enterprise*** which ensures the continuation of RASSP after the end of government support in 1997.

The key to meeting these goals is to develop an open and flexible system which uses a demonstrated, measurable, repeatable, and transferable process. In structuring the Lockheed RASSP program around this key, we had deal with several issues. Our resolution of these issues has significant impact on the structure of our program and on its long-term success.

Chief among these issues is the realization that for RASSP to meet its goals of ***Proliferation***, the process developed by Lockheed must be able to be used without financial hardship by companies new to RASSP. In other words, since RASSP intensively uses many different types of EDA tools, the introduction of RASSP to a new user must not require him to abandon all the EDA tools he currently is using. The reason for this is based not just on the high acquisition cost of EDA tools and their associated workstations but on the enormous investment companies have in training their employees to use a specific tool set. From this realization came the decision to structure the Lockheed process in such a way as to accommodate RASSP newcomers without penalizing them for their current investment.

Our approach to a second, but equally important, issue has also had a large influence in shaping the program. The EDA industry in America is a $1.5 billion per year indus-

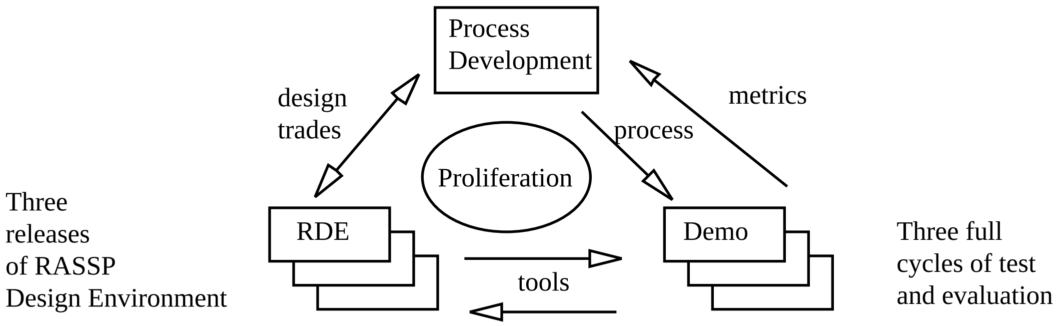

Figure 1: Our approach to RASSP combines process development, RASSP Design Environment development, Demonstration and Proliferation

try. Lockheeds approach has always been to harvest the best products from this robust industry. Since the EDA market is intensely competitive, new products and new companies are constantly appearing in response to the evolving DSP market. This harvesting process, which has been used so successfully in Lockheeds application of EDA tools to date has led to the concept of ***State of the Shelf***. This powerful idea, pioneered by Lockheeds ***Signal Processing Center of Technology*** is successfully coupled to the concept of model years in the development of DSP-based systems. In this concept, the use of state of the shelf in the implementation of a model year upgrade reduces risk and cost and dramatically reduces the time required to field a model year upgrade of a processor.

There are, however, several areas in which current EDA tools are deficient or missing altogether. These *holes in the fabric* are being mended by a series of technology-based contracts funded by the ARPA-Triservice RASSP program office. In many cases these activities, whether based at universities or in industry, will lead to new tool functionality which will be available commercially. These new tools will, in turn, increase the state of the shelf for EDA tools.

2.0 Approach

In order to meet the goals of the program, a well- defined approach to implementing RASSP is required. This approach is based on four equally important program pieces, Figure 1. The first of these is to provide a ***flexible methodology and environment*** for users of the process. This process can then be easily adopted by the DoD industrial community. As discussed above, this allows a user to keep operating with an established base of tools.

The second part of our approach is based on the provision to the user of a development paradigm which supports large distributed environments which are spread across geographically disparate teams. This part of our approach includes tools for remote, cooperative work. Also included is a flexible environment which includes the incorporation of a *pay-per-use* concept for access to tools.

A central part of the ***RASSP Design Environment (RDE)*** is the ***Enterprise Framework***. Working in partnership with the ***CAD Framework Initiative (CFI)***, and ***Cadence, Inc***., the Lockheed RASSP framework will be CFI compliant. The documented interface requirements which are arising from this effort are expected to lead to the publication of comprehensive standards for all frameworks.

The third leg of the Lockheed approach is to ***demonstrate*** unequivocally the success of the methodology and the RDE. This is being accomplished by upgrading the InfraRed Search and Track (IRST) signal processor currently in use on the F-14D. With the strong support of the US Navy and of the ARPA Advanced InfraRed Measurement System (AIRMS) program office, the first model year of the IRST will be flight tested on-board the AIRMS aircraft at China Lake in January 1995. This effort began in February 1994. Thus, in ten months a complete virtual prototype of the system will have been built and tested. Actual construction of hardware will not start until the fall of 1994. This program is on schedule for a January test. Only the RASSP process of ***complete simulation in VHDL and Ada*** for the virtual prototype, followed by fabrication of the flight hardware of Model Year 0 can meet this timeline.

In addition to the Demonstration, Lockheed is executing a series of ***Benchmarks*** which measure the process improvement of our approach in an incremental way. The first of these benchmarks involves the virtual prototyping of a ***Synthetic Aperture Radar*** for application to an ***Unmanned Air Vehicle***.

The fourth part of our approach is to ***proliferate*** the process widely. Lockheed is dedicated to the proliferation of

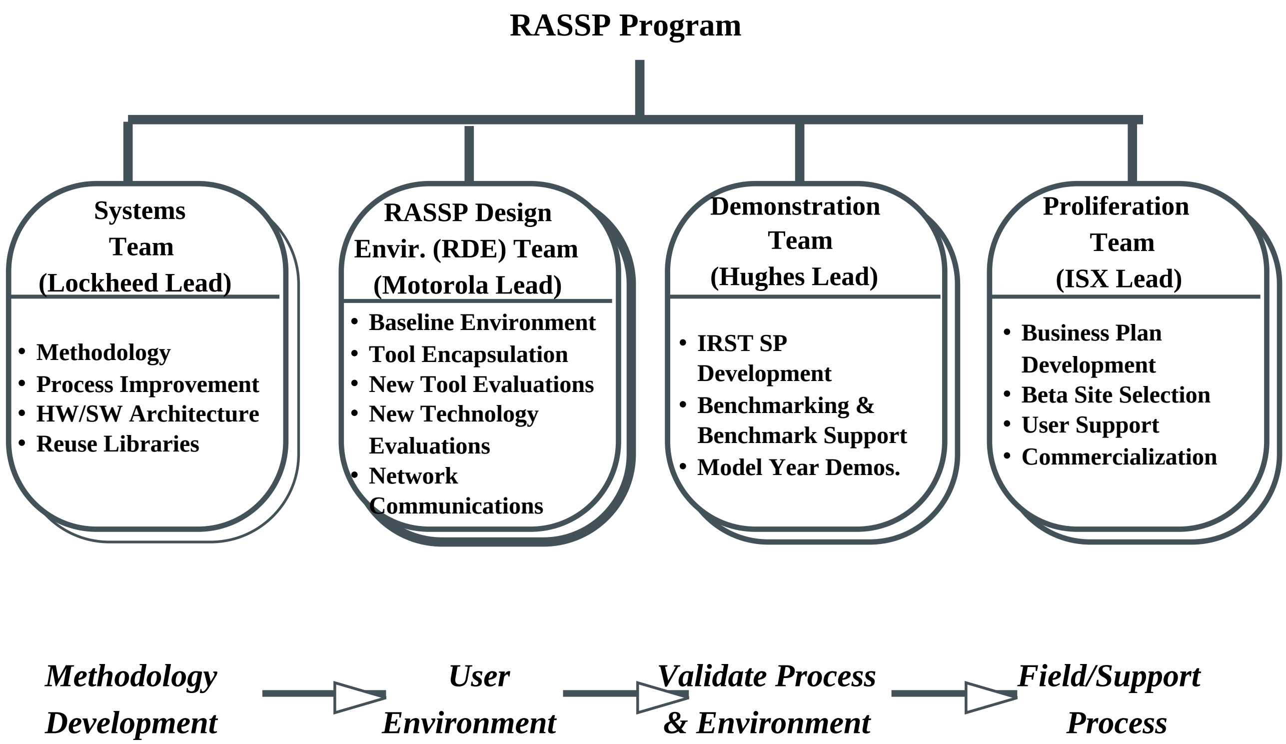

Figure 2: The Lockheed Sanders RASSP Team is made up of four Integrated Product and Process Development Teams (IPPDTs)

RASSP. An example is that the original concept of a ***facilitator*** on the program came from Lockheed. Proliferation to a range of users also provides a way of verifying our process. It also gives us a way to get feedback on the strengths and weaknesses of our process.

2.1 Program Organization

In order to meet the goals of RASSP and to execute the approach that we selected, Lockheed teamed with Motorola, Hughes Aerospace, and ISX. The technical work on the program is split nearly equally between Lockheed, Motorola and Hughes while ISX has a small but significant role.

These four companies have widely varying styles and business cultures. They are also spread out all over the United States. As a result, we have been forced to confront the issue of creating first a large virtual program and finally to face the challenge of creating a large virtual corporation.

Because of the success which Lockheed and the US Air Force has had on the F-22 program with the use of ***Integrated Product Teams***, we chose to use a similar management technique on RASSP. Our program consists of four ***Integrated Process and Product Development Teams (IPPDTs)***. These four teams include ***Systems, Design Environment, Demonstration, and Proliferation,*** Figure 2.

Lockheed leads the Systems team as well as being the prime contractor on the program. Motorola has the lead responsibility on the Design Environment, while Hughes leads the Demonstration team. ISX has the responsibility for the Proliferation effort. All team companies share each of the team's tasks. This leads to the concept of ***single responsibility, shared execution***. This has worked well on the RASSP program.

Typical of the innovative ways used to erase the geographical distances separating the team members is the extensive use of the ***Internet***. By using T-1 lines through out the team, we are able, for example to carry on ***video conferences*** between desks separated by thousands of miles. At the same time engineers can share workstation screens, send encrypted files between ***fire-wall protected servers*** around the country, and can access our ***MOSAIC*** server with its homepage directions to current RASSP activities.

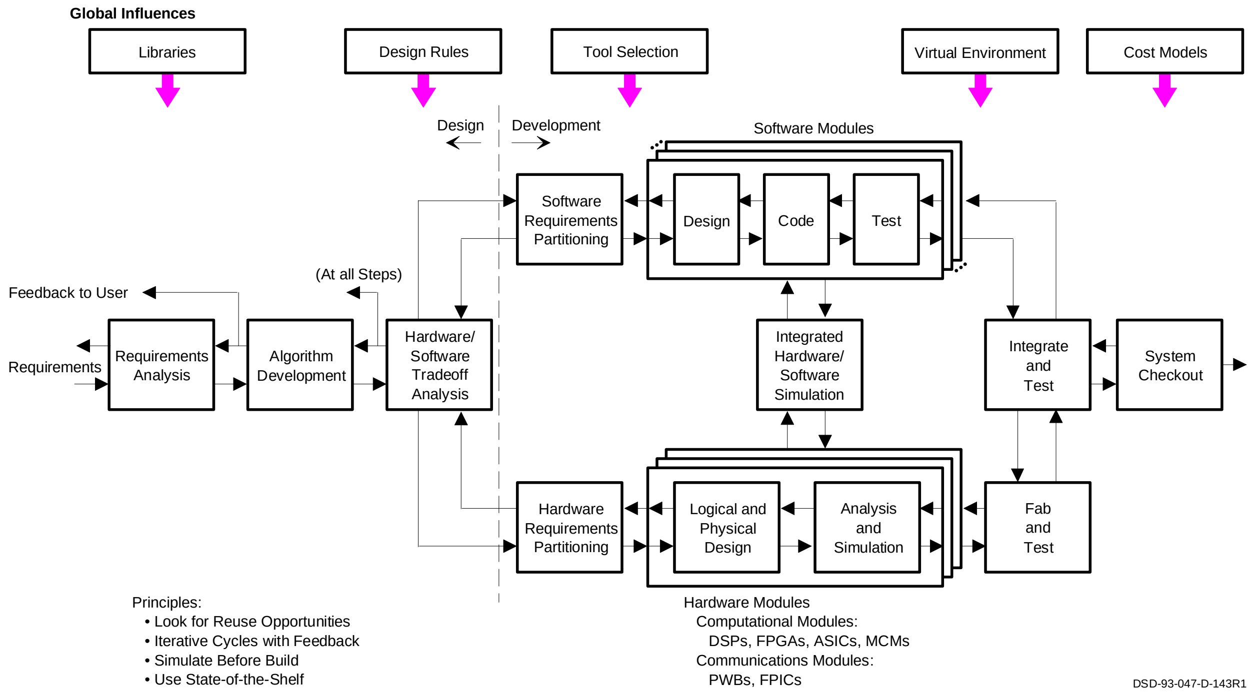

Figure 3: The RASSP Development Methodology work top-down from requirements to completed system with feedback to the user at all stages and with an integrated hardware/software simulation in VHDL as a key.

Concurrently, tools sited at one team's location can be used remotely, or can be transferred through various ftp protocols.

2.2 RASSP Methodology

The Lockheed methodology is definable by looking at its four fundamental parts, Figure 3. The first of these parts is a systematic and codified top-down design process integrated into an iterative approach to model year development. A second key attribute of the methodology is the emphasis on completing the hardware/software trade-off analysis before the system architecture selection.

The last two parts of the methodology are closely linked. We use a virtual prototyping technique in which a complete VHDL model is developed to reduce integration risks. The last piece of our methodology involves delivery of a complete description of the system as a VHDL model. This includes source code for all programmable processors in the design. All source code is written in Ada.

The emphasis on virtual prototyping improves the quality of design, documentation, and error checking. This reduces mistakes that can have costly consequences which do not appear until late in the development cycle. Our objective in RASSP is to produce a top- down design methodology in which a design is successively refined as a growing, verifiably consistent data package over the course of its development. The initial functional requirements are captured and ported into a simulation environment supported by a VHDL simulator. This ***"executable requirement"*** is refined until it becomes a complete ***"executable specification"***. This acts as a test bench and also provides the requirements for the next lower level of the design.

This top-down development process is used over the life cycle of a signal processor in an iterative way. These iterations allow for ***continuous improvement,*** i.e., RASSP Model Year Upgrades, of the signal processing system throughout its development and deployment. Upgrades can include functional improvements, repackaging for reduced power, cost, weight, or volume, or to replace parts out of production with those more readily available. The functional and performance specifications from one model year become the executable specification for the next. The ***hierarchical VHDL*** description provides for easy reuse of any downward chain, and redevelopment starting from any upward intact chain. The corresponding ***Ada*** code provides for ***software reuse*** in a similar manner.

2.3 RASSP Design Environment

If the center of the RASSP process revolves around the RDE, then the heart of the RDE is the ***Enterprise Frame-***

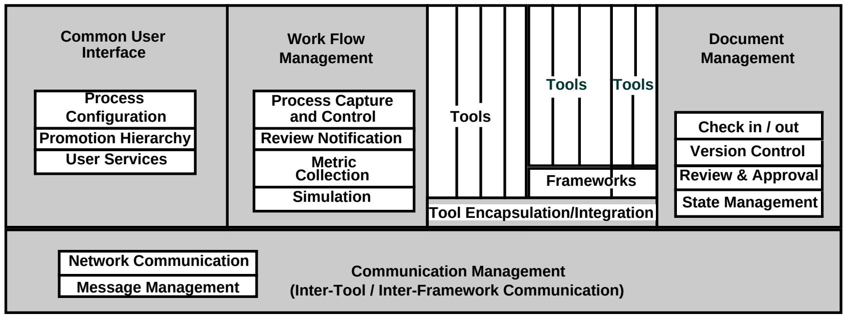

Figure 4: The RASSP Design Environment consists of a Common User Interface, Documentation Management, Tool Encapsulation/Integration, Communication Management, and Workflow Management.

work (EF). The EF includes five major functions, Figure 4. All of these functions together support an integrated design environment which is ***standard-based***. And as was discussed earlier, the RDE includes the capability of being easily and individually tailored to each user. And, finally, the RDE is constructed so as to support a ***"Pay-Per-Use"*** concept.

The RDE/EF, as noted, consists of five major elements. These include a ***Common User Interface (CUI)***. This is a ***UNIX X-Windows*** based Graphical User Interface (GUI). The CUI is used to provide a repeatable way to launch tools and for accessing framework services. A second important part of the EF is Document Management. The ***Document Manager (DM)*** provides two important capabilities. It gives the EF the ability to check in and check out documents. It also allows for the tracking of the state of documents as they are generated, reviewed, and approved.

A third important function of the RDE/EF is to provide ***Tool Encapsulation/Integration***. The ***"wrapping"*** of tools in a common standard script-based encapsulation allows for all tools to interface with the EF in a standard way. This lets us incorporate a wide range of tools with the ability to substitute alternative tools to perform the same function. This, in turn, allows the RDE/EF to support alternative system development strategies. Finally, encapsulation allows for the *incorporation of hooks* that support "Pay-Per-Use".

The ***Communications Manager*** is that part of the RDE/EF that provides communications services that allow document distribution, review, comment collection, approval and release. It also provides the capability for private and broadcast messaging, and multimedia teleconferencing.

The final part of the RDE/EF is one of the most important. The ***WorkFlow Manager*** controls the execution of the RASSP development process by guiding the user through the appropriate steps of the process. It invokes tools automatically along with appropriate data format translators. It also provides the interface to the project scheduling, costing, and tracking systems used by the RDE.

2.4 RASSP Demonstration

The ***Demonstration*** is a key part of developing the RASSP process and tools. By developing actual hardware and software systems, the demonstration assesses the usefulness and performance of the RASSP design environment and its associated tools. It provides a ***measure*** for the design complexity and process maturity, and allows us to ***quantify*** progress toward the four-fold improvements which are the primary goals of RASSP. The demonstration, then, allows us to ***test*** the methodology and the RDE, and it lets us demonstrate the Model Year Upgrade concept.

As was discussed earlier, the specific demonstration in the Lockheed RASSP program involves upgrading the ***Infra-Red Search and Track*** signal processor on the ***F-14D*** aircraft, Figure 5. In the demonstration we will build a virtual prototype using multi-leaf VHDL models and software whose source code is written in Ada. This prototype will be used to support three Model Year Upgrades (0, 1, and 2). ***Model Year 2 will fly*** on the ***Bloodhound II F-14*** at Point Mugu, California in 1997. ***Model Year 1 will fly*** in 1995 on an ARPA special mission testbed aircraft. Model Year 0 will be operational in the Hughes E/O Mission Integration Laboratory in the fall of 1994.

2.5 RASSP Proliferation

The primary purpose of the ***Proliferation*** function in the Lockheed program is to successfully ***transition our RASSP process*** to other organizations. This team also ***interfaces with the Educator/Facilitator*** and with standards organizations such as ***CFI, SAE, and IEEE***. They

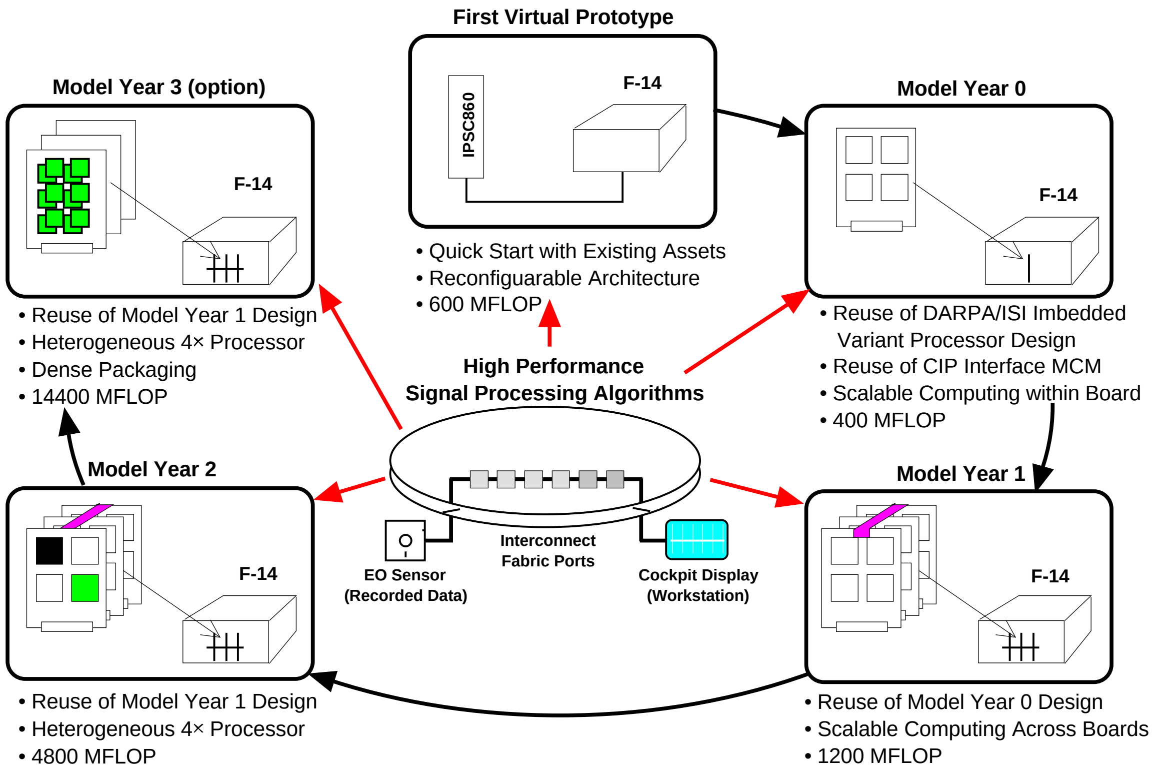

Figure 5: The RASSP Demonstration will provide three iterations of an F-14 IRST processor.

also help coordinate the activities of the ***University and Industrial BAA winners*** with the Lockheed RASSP team.

3.0 Accomplishments

Good progress has been made during the first year of the contract in all areas of the RASSP program by the Lockheed team. Some of the more significant accomplishments are discussed and this section closes with a look at our objectives of the second year of the program.

3.1 RASSP Methodology

The Systems team has met its goals by meeting three primary objectives. The team has demonstrated a ***top-down development*** approach that is VHDL-based. In doing this a process to ***capture, allocate, and specify*** requirements has been demonstrated, Figure 6. Other activities include the release of ***VHDL style and modeling guidelines***, and the improvement of the selected VHDL performance modelling tool. This has resulted in improvements in both formatting and porting of information input to and produced by the tools.

Performance-level modelling has been incorporated into the design approach. Coupled to this is a model for the incremental development process which was formulated early in the program and refined several times over the last few months. We have also developed a detailed process description as the basis for the ***RDE/EF Workflow Managers.*** Included in this activity is the establishment of ***Process Models*** that are computer-based.

In the ***Architecture*** area several different signal processing problems have been selected for analysis. ***Dataflow models and computational cost models*** for signal processing problems were established. This was followed by initial ***simulations*** of the chosen architectures and the creation of a set of ***library interface specifications***.

3.2 RASSP Design Environment

The ***0.1 Release of the RDE*** was completed on time last May. It contains significantly more features than originally planned. Three major features of Release 0.1 include the inclusion of a ***Document Manager (DM), Full Problem Reporting,*** and ***Tool Launching*** of nearly 40 different tools.

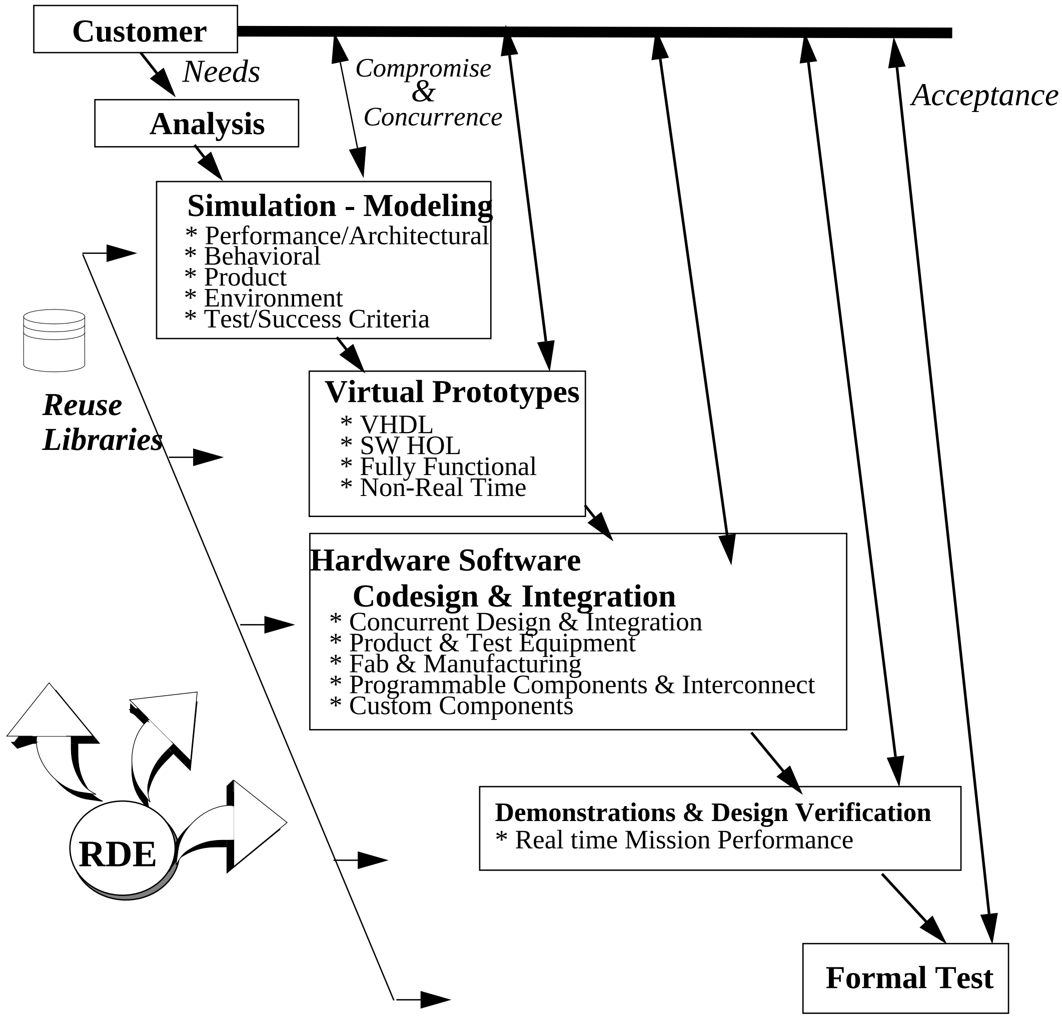

Figure 6: The details of the first release of the RASSP Development Process have been completed.

To support this activity the ***RDE Top-level System Architecture*** definition was completed along with initial documentation of the Design Environment. ***Tool/Technology Evaluation Methodologies*** were defined and the ***Manufacturing Interface*** requirements were released. The defined RDE architecture was built and integrated formally into Build 1. To support these activities, network communications and the associated roadmap were established.

We have completed an in-depth evaluation of ***CAD Enterprise Frameworks***. This has included the issuing of a formal RFI, and presentations by vendors, followed by long-term in-house evaluations. After a multi-stage down select during which the CAD framework candidates were tested concurrently at Lockheed, Hughes, and Motorola ***against 66 requirements*** chosen by the team as crucial to an EF, a framework and supplying CAD vendor has been selected. This vendor is ***Cadence***. They have teamed with us to produce by ***September 1995 release 1.0 of the EF.*** CFI has agreed to support this effort by producing from the Lockheed EF requirement document and from joint activity with the Lockheed/Cadence team a set of standards which will make the ***RDE/EF a CFI-compliant enterprise framework***.

To support the virtual nature of the RDE formal establishment of ***a network based communication system*** has been completed. This allows the secure ***(fire-walled and encrypted)*** use of e-mail, bulletin boards, file transfer, screen sharing, and ***video teleconferencing over the Internet.*** Our customer community has access to the system as well, which facilitates communication and reduces the movement of documents in paper form.

3.3 RASSP Demonstration

Some of major accomplishments of the Demonstration team have already shown the power of the RASSP Model

Year Upgrade approach. Because of the way in which the Model Years 0 and 1 work have been structured, the change of the basic demonstration from the development of a new IRST for the F-22 to the upgrade of the ***IRST on the F-14D*** was accomplished with no schedule or cost impact.

Model Year 0 will build a virtual prototype of the chosen architecture and algorithms. This prototype is ***VHDL and Ada based,*** and will be tested on an E/O testbed in 1994. After validation of the prototype design against the VHDL-based requirements, Model Year 1 Build will begin.

Model Year 1 entails the building of a VME-based Mercury Raceway multi-computer environment for the ADA software running the selected spatio-temporal algorithms. This hardware model year will be flown on ***the ARPA AIRMS testbed aircraft*** in January 1995. The build requires a number of custom boards to be constructed and integrated into the Mercury based IRST. That all of this can be done within one calendar year from the start of the Demonstration effort is a testament to the strength of the RASSP paradigm.

To support this aggressive program the team has developed a ***VHDL description of the IRST processing*** and its interfaces, has identified a candidate architecture after a series of architecture trade studies, and has produced a performance model of this architecture. ***Georgia Tech*** has been brought into the team to produce ***VHDL*** models of components crucial to the success of the Virtual Prototype. Among the models being developed is a VME bus model and an Instruction Set Architecture (ISA) model of the Intel i860 processor. This ISA model will allow the Mercury Operating System (MCOS) to run on it with the same fidelity as on the real chip. This in-turn allows the compiled ***Ada application software to run on the ISA model***. This is a key to successful virtual prototyping. Other models being developed include the ***Power PC 601, and the Analog Devices SHARC***. Since these models are being developed by RASSP, they will be ***freely available*** to all without restriction. The other RASSP prime contractor (Martin-Marietta) is, in fact, planning on using the Lockheed developed ISA model in their program.

3.4 RASSP Proliferation

The Proliferation team has made significant progress in three areas. The first of these is the design and establishment of the ***Visionary Demonstration*** (also referred to as ***"the Hot Mockup"***). This tool is used as a testbed of anticipated capabilities of RASSP and serves as a powerful demonstrator to help answer the question "what is RASSP". This tool captures visually the RDE as we see it in four years, and also captures the Methodology. It includes a description of the RASSP team and its organization and can lead a user through an example of the Lockheed RASSP process being applied. It is a ***system engineering tool*** and an ***evolutionary product*** that reflects our current progress. It features a Mac-based design that is portable, and which is easily distributed to RASSP team members, end users, and customers. The Mockup includes ***Operational, Program and Technological Views.***

The Proliferation team has also led the program in ***establishing World Wide Web and Mosaic servers and homepages***. A Lockheed RASSP Email Informational Address has been established along with an Information Line ***(1-800-99RASSP)*** which includes automatic Fax-back service.

The proliferation team is leading the ***commercialization of RASSP.*** A market survey has been completed which strongly supports the formation of the ***Electronic Information Corporation (EIC)*** with its ***Pay-Per-Use*** access to tools and the RDE/EF. Several major CAD companies have already agreed to offer their tools in this venue with many more expressing interest. Lockheed, Hughes, and ISX have allocated corporate profit to begin the process of forming EIC and the products it will offer. Prime among these products is ***CADEXPRESS (sm)*** a Federal Express-like Internet-based delivery system of the RDE/EF and tools. The EIC corporate name has been registered in Delaware, and incorporation activity has begun.

4.0 Future Work

The next year should see a continuation of on-budget on-schedule performance by the Lockheed RASSP team. A look ahead reveals several major thrusts for the next year. The refinement and further expansion of the Lockheed RASSP process model will lead to two additional "builds" of the Methodology. This, in turn, will drive the evolution of the Enterprise Framework. The partnership with Cadence and the associated support by CFI is expected to lead to a release of the first Build of the EF in September 1995. The standardization of interfaces between elements of the EF as well as between the EF and the elements it communicates with is expected to have a profound effect on the CAD market,. This will be a major enabler of the EIC CADEXPRESS concept. Flight test of the IRST will complete in Spring 1995. Concurrent model development for the virtual prototype of the F-14D IRST will take place in this time frame, too.

5.0 Summary

The first year of the Lockheed RASSP program has been completed successfully. No major program changes have been required. Indeed, the new USN demonstration is being done with no cost or schedule impact. Our Process and Methodology is defined and has been reviewed in detail by our customer. Iterative builds of these continue. Major effort has been expended to define a RASSP Enterprise Framework. The success of this is measured by the new Lockheed/Cadence/CFI partnership to produce a CFI compliant framework by September 1995. Our commercialization effort is proceeding smoothly. In September 1995, the mid-point of the contract, we expect to have continued the established technically-compliant on-time on-budget performance in which the Lockheed team takes great pride.

6.0 References

The following are references for documents relating to both the RASSP program in general and to Lockheed Sanders RASSP program specifically. Many of these references are available for electronic distribution.

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Acknowledgment:

The Lockheed Sanders, Inc. RASSP team is under contract to the Naval Research Laboratory, 4555 Overlook Ave., SW, Washington, DC 20375-5326. The Sponsoring Agency is: Advanced Research Projects Agency, Electronic System Technology Office, 3701 North Fairfax Drive, Arlington, VA 22203-1714. The Lockheed RASSP team consists of Lockheed Sanders, Inc., Motorola, Hughes, and ISX.