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Title: Agile Infrastructure for Manufacturing Systems(AIMS),
A Vision For Transforming the US Industrial Base.

Abstract: AIMS will create an open, scalable infrastructure for inter-enterprise distributed agile manufacturing, and demonstrate its effectiveness in a 24-month pilot conducted by five major corporations. When fully developed, it will enable a production operation in one company to utilize production resources in another as a seamless extension of internal capability. AIMS will unify the Nation's industrial base through a common information infrastructure that will enable the virtual production enterprise; accelerate conversion to dual use with new production delivery channels; and strengthen the competitive position of the Nation by allowing focus on core competencies without sacrificing breadth of capability. This paper discusses the business processes, information technology, and manufacturing technology encompassed by the project.

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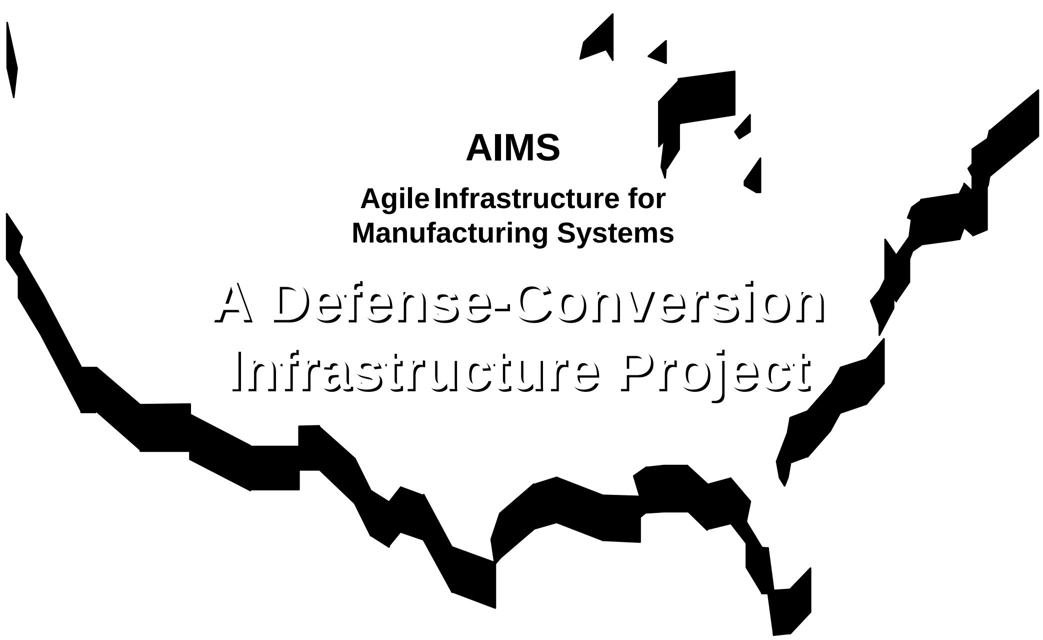

Agile Infrastructure for Manufacturing Systems **(AIMS)**

A Vision for Transforming the US Manufacturing Base

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1. Overview

Thirty years of Cold War have left the US with two parallel industrial infrastructures—one for defense, the other for general commerce. Each sector relies on distinct technologies, production processes, and business practices. This legacy has made defense systems unaffordable and encumbered our industrial competitiveness. The new world order demands a unified industrial base where defense and commercial products share dual-use technology and are manufactured on agile production processes that respond rapidly to changes in customer requirements and demand.

This paper describes a shared vision and evolutionary plan for unifying the Nation's industrial base through a common information infrastructure. It reports on work over a nine-month period by a team of 5 major defense and commercial manufacturers who will form a consortium to execute the pilot and growth phases of the plan.[1]

The AIMS team proposes to create an open, scalable infrastructure for agile manufacturing, and to demonstrate its effectiveness in pilot production. The infrastructure will provide standardized ways of accessing a wide variety of agile production services over local area networks as well as the Internet. The infrastructure is open because anyone will be able to offer services; it is scalable because no distinction is drawn between services available on one's own shop floor, those obtained from other parts of one's company, and those obtained from other companies across the country. When fully developed, AIMS will provide access to a national network of agile manufacturing services that any company can utilize as seamless extensions of their own internal production capabilities.

During the pilot phase of the AIMS project, lasting 24 months, each of the five AIMS participants will offer flexible machining services to each other over the Internet. These services initially will be limited to simple prismatic parts. The pilot will define standards for part descriptions and for

[1] The companies are Lockheed Missiles & Space Co., Martin Marietta, Texas Instruments, and two other major manufacturers. Technical support was provided by EIT and Lockheed AI Center in collaboration with Stanford University and UC Berkeley. The plan has been submitted for a major defense conversion initiative by ARPA.

the network interfaces through which manufacturing services are requested, as well as the procedures for certifying that a supplier complies. In addition, benchmarking and agility metrics will be formulated so that alternative suppliers can be objectively compared. With this framework of standards, qualifying procedures, and agility metrics in place, the AIMS network will be poised to grow rapidly into a national infrastructure for agile manufacturing.

The objective during the growth phase (months 24-36) will be to populate the AIMS infrastructure with a broad range of manufacturing processes, providers, and third party value-added services (e.g., brokers, part and process libraries). Training and outreach will be handled by established manufacturing extension service agents such as Department of Commerce Manufacturing Technology Centers, ORNL, and NCMS teaching factories using training materials developed by the AIMS consortium. The consortium will also develop and distribute software "starter kits" that make it easy to use and offer manufacturing services through AIMS.

Companies utilizing AIMS' virtual production environment will be able to manufacture and assemble products at lower cost and higher quality with less risk and shorter lead times. These benefits will come principally from two sources: 1) a greater reliance on core-competencies throughout the product realization process; and 2) affordable solutions to the costly problems of rapid prototyping and high-mix, small lot production.

More generally, an information infrastructure such as AIMS will accelerate the conversion of both defense and commercial facilities to dual use by encouraging outsourcing to balance loads, handle surges, and access specialized processes. For example, DoD contractors would be able to keep busy with commercial jobs during slack times, and rely on commercial suppliers during surges. The infrastructure would also strengthen the competitive position and skills-base of the Nation's manufacturers and suppliers by allowing each to focus on core competencies without sacrificing breadth of capability.

If the US manufacturing base is to thrive in the increasingly competitive environment, it must undergo a significant and swift transformation. In presenting the AIMS project at an early stage, we hope to enlist others to join with us in bringing about the necessary changes. The remainder of this paper is organized as follows. We first present an overview of the AIMS infrastructure and a series of scenarios that demonstrate its potential to impact manufacturing productivity. We next describe the innovations in business processes, information technology and manufacturing technology required to implement the scenarios, and outline a specific plan of action. We conclude with a discussion of the likely impact of AIMS from a business and economic perspective.

2. Vision

The AIMS project will create a national infrastructure for agile manufacturing, focusing on rapid prototyping and fast-turnaround production of small lots. AIMS will be piloted in the domain of precision machining and then extended to other fabrication and assembly operations. Our goal is to create an integrated network of services that encompass key aspects of agile manufacturing from procurement to shipping, and that makes no distinction between whether jobs are done in-house or outsourced to subcontractors.

Underlying AIMS is the concept of a network of certified manufacturing services, spanning numerous companies, linked via the Internet. A certified supplier is one that employs standard business processes, product data formats, and network interfaces. (see Figure 1.) Customers interact with these suppliers using structured messages, requesting information about costs, capabilities, and availability, soliciting bids, placing orders, and so forth. They can communicate with a provider directly or via third-party directory and brokering services.

In the AIMS environment, it makes little difference whether a supplier of production services is a multi-national company across the globe or a workcell across the shop floor. In either case, the relevant issues are the same: how much will a part cost, when will it be ready, and what quality to expect. To operationalize this abstraction, we introduce the concept of agents. AIMS agents encapsulate production resources at any level, transforming them into suppliers capable of responding to service requests.

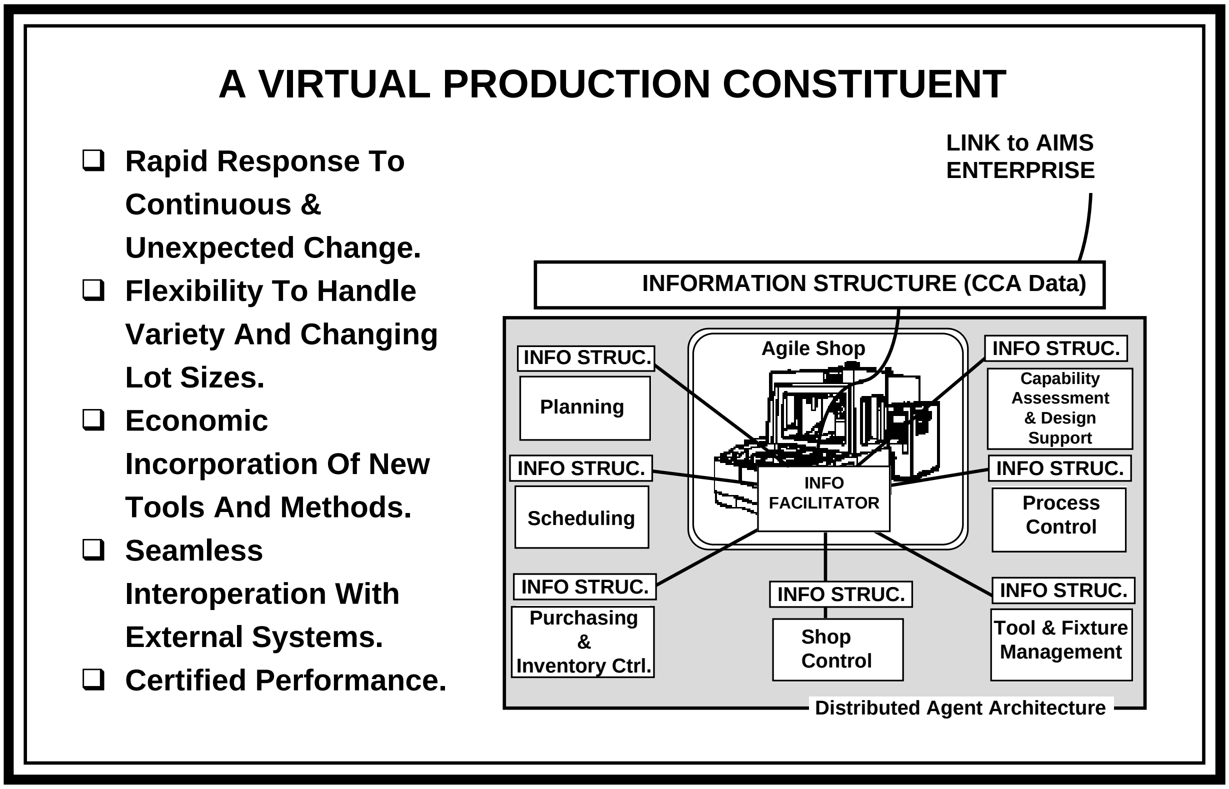

Figure 1. A certified manufacturing service.

To maximize agility, a production service may itself be a virtual enterprise, relying on other network services to do its work. For example, corporate-level agents delegate jobs to the shop-floor agents that actually perform work; shop-floor agents, in turn, may off-load jobs to other workcells. AIMS agents can use brokers to locate appropriate providers, or to bid on jobs for themselves. They can also call on providers of manufacturing support services, such as scheduling and process planning.

During the pilot phase of AIMS, each of the five team members will establish standardized precision machining services on the net. These services will utilize existing production facilities whose legacy manufacturing systems are encapsulated by agents programmed to emulate the responses of a certified supplier. Each team member will decide for itself at what level to encapsulate its production resources. Companies that have invested in sophisticated shop floor control systems are likely to encapsulate their entire facility.

Figure 2 depicts the AIMS infrastructure as described above. Each black dot represents an agent that provides agile production services. The agents in the unlabeled central cloud encapsulate entire companies. A company's services are provided by agents that represent specific divisions or factories. These divisional agents can be further decomposed into agents representing specific production resources, such as a flexible machining center. What emerges is the notion of a scalable national infrastructure, linking numerous agile manufacturing services at multiple companies and levels of production.

The AIMS infrastructure provides manufacturers with unprecedented flexibility and responsiveness. Services can be added or taken out of service at any time, with incremental impact on capacity, simply by informing the appropriate directories and brokers. Resources can be allocated on-demand and loads continually balanced through an open bidding process. These are the hallmarks of an agile infrastructure.

To demonstrate the expected benefits of AIMS, we present three scenarios in which the same part is first prototyped and then produced in small lots for just in time delivery. The scenarios take place: 1) in today's job shop environment, 2) in 18 months, when the initial AIMS pilot is fully operational, and 3) in 5 years when the AIMS infrastructure is fully developed.

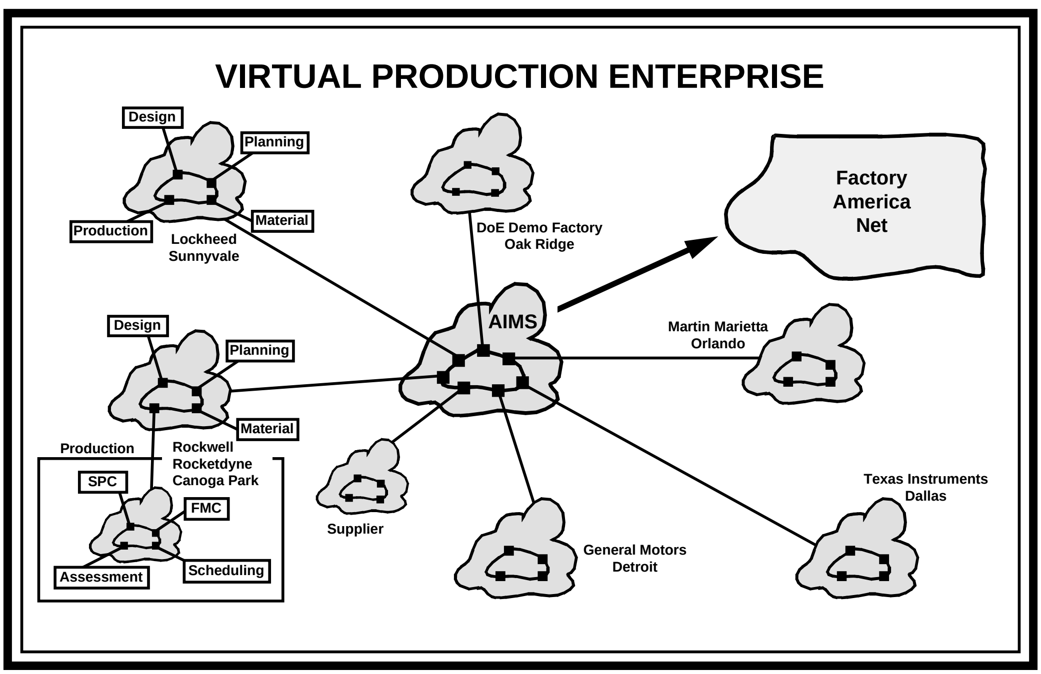

Figure 2. Agile Enterprise (Virtual Corporation)

Today

Today, companies rely on internal shops or a few familiar contractors for prototyping and JIT production. Establishing relations with new suppliers can take months because everything from terms and conditions to CAD formats must be negotiated, and the supplier's capabilities must be validated. Drawings of the required part are sent out to at most a few shops for quotation. The drawings are transmitted via Fax, modem or computer tape, and often must be reentered manually into the shop's CAD system. Each request for clarification (e.g., a missing surface finish or tolerance specification) can take days. Depending on the part's complexity it can easily take weeks to months to plan and schedule the prototyping run, and get the first part back to the design engineer. If mistakes are made or difficulties encountered necessitating design changes, the overall cycle time may increase by 50% or more. Subsequent production runs must be scheduled around other, higher volume work and are vulnerable to peak loading and equipment breakdowns, so inventory buffers are needed. In short, while rapid prototyping and Just-in-Time (JIT) production are done routinely, they require extensive prior arrangements and seldom live up to their names.

18 Months

In 18 months, using technology that is already largely available on the Internet, the initial 5-company AIMS pilot will be fully operational. From his everyday computing desktop, our designer sends e-mail to his company's internal prototyping shop as well as those of the four other team members, with the subject line: "CCA". In less than a minute he receives back standard datasheets detailing each shop's capabilities, costs and availability (CCA). These datasheets look just like typical entries in a Thomas Register (complete with tables, graphics and pictures), with one key difference: the CCA data reflect up to the minute conditions on each shop floor. The data were inserted only seconds before mailing via live links from each shop's MRP, production control, and statistical quality assurance (SQA) computer systems.

The designer selects 2 shops that have been pre-qualified for machining magnesium to .005 tolerances, and have capacity immediately available. He e-mails a bid package with the subject line: quote. The multimedia (MIME) message contains a set of specifications and a pointer to files containing design drawings, that the shops can download at their convenience.

There are no problems with engineering and process data exchange because participants in the AIMS pilot support IGES and PDES, as well as the feature-based design standards emerging from NIST's Rapid Response Manufacturing (RRM) project.

Each potential supplier uses the engineering data to develop a process plan and estimates of cost and delivery. These estimates are returned to the designer via E-mail.

Buyers and sellers of AIMS services routinely discuss design refinements and engineering changes via multimedia E-mail and desktop conferencing tools. Using the multimedia collaboration tools, a workstation session can be captured, complete with mouse gestures and spoken comments or questions, mailed and then replayed on the recipients workstation. Participants in real-time conferences can jointly run applications and share data across platforms. Design problems that once required a trip across town or across the country to resolve are addressed without delay. Collaborating on the Internet eliminates the man-months of effort previously required at the start of projects to set up ad hoc information sharing infrastructures.

Standard AIMS electronic order forms (containing standard terms and conditions), are E-mailed to the shop's order entry system. The job is logged and forwarded to the production control system, where it is scheduled for the next day. By week's end, the prototype arrives via an overnight delivery service.

Production status can be monitored at any time using Information Navigator (an interactive hypertext viewer) to access production schedules, work-in-process, and other information related to the order. When the job is complete, quality certification data is sent.

Subsequent production runs will involve many of the same transactions involved in prototyping. Since the initial process planning and negotiations need not be repeated, 1-day turnarounds on small lots is quite feasible. The major obstacles to reliable 1-day service are likely to be peak loading, equipment breakdown, and materials shortages. These risks are readily mitigated under AIMS by running prototypes through several shops and then allocating jobs dynamically based on current costs and availability. Unlike current practice, the purpose of the prototyping runs is not to qualify the shops, since they are already pre-certified. Rather it is because AIMS members have made the pragmatic decision to standardize on design rules and CAD formats, letting each shop do its own process and fixture planning.

To summarize, although most work processes associated with prototyping and production will still be only partially automated 18 months from now, the average turnaround time for prototyping shops can decrease by nearly an order of magnitude because of AIMS. This improvement results from pre-qualification of certified suppliers, the standardization and streamlining of processes, and the elimination of delays and errors associated with CAD re-entry and paper-based transactions.

5 to 10 years

Looking ahead, we shall speculate on AIMS' potential to revolutionize US manufacturing. The scope of what is envisioned here goes far beyond the proposed project. However, everything described is a realistic projection, given the existence of an enabling infrastructure and a broad national effort to populate it with services.

Numerous incremental refinements have transformed the initial AIMS pilot into a dynamic electronic marketplace where hundreds of agile production services compete for attention. A variety of directory, brokering and advertising services help engineers locate new services nationwide. They include an electronic white pages (names), yellow pages (services) and classifieds (daily specials). Distinctive icons, representing frequently used services, clutter a corner of our designer's computer desktop. When selected, these electronic business cards transform themselves into catalog pages or order forms.

Some engineers still communicate with service providers via multimedia mail. Most, however, access services interactively using their favorite AIMS-compliant Internet cockpit. Every service offers a hypertext menu like the one shown in Table 1. Selecting any item leads to further interactive possibilities such as an electronic form to complete, or a multimedia presentation. As companies vie for attention, datasheets increasingly resemble multimedia advertisements. Some update CCA data in real time; others invite customers to click on highlighted items and obtain further information, often a slick animation or video clip. When the engineer is ready to order, the electronic form that appears will have many of its entries already filled in, based on these information inquires. Interacting with services via hypertext eliminates many current barriers to spontaneous electronic commerce, such as having to learn an idiosyncratic graphical interface, login procedure, or EDI transaction set before using a new service.

A variety of in-house and third party brokering services are available to match customers and providers of production services. Many large companies, such as Lockheed have set up internal brokers that help their engineers decide whether to fabricate a part in-house or outsource it. These brokers maintain lists of approved outside suppliers that they consider best of breed. They also advertise services their companies provide on an outsourcing basis to others.

Third-party brokering services run the gamut from basic referral services to full-service procurement agents. The former specialize in a given process and simply aggregate and rank order CCA data from alternative providers. The latter handle all aspects of bidding and procurement, assembling a bid package, sending it to scores of qualified suppliers, and evaluating the resulting quotes. Small job shops gain access to national markets while large primes and OEMs gain access to a much broader supplier base.

- supply standard CCA (Cost/Capability/Availability) datasheet
- estimate cost and deliver for this part
- provide a firm quote
- check this design and provide a DFM critique
- generate a process plan for this design
- design setup and fixturing
- submit an order
- check status of order
- request SPC part data
- schedule delivery
- engineering change (please acknowledge)
- request on-line video conference

Table 1: Sample Interface for Agile Production Sites

Some full-service agents run a public bidding process, in which evaluations are based on specified weightings for cost, delivery time, and quality. The winning bid is posted for all responders to see. Their 5 percent fee is considered a bargain since the entire bidding process is completed within hours, eliminating procurement backlogs. Moreover, production costs are reduced nearly 10 percent on average, because posting winning bids drives down market prices. Occasionally, much greater savings are realized, for example when vendors with idle capacity bid aggressively to keep their skilled workers on the job.

The most sophisticated brokers provide on-line access to the latest experimental fabrication processes, whose developers (typically university researchers) are not prepared to deal directly with the public. These brokering services are modeled after the pioneering MOSIS VLSI fabrication service. UC Berkeley and Stanford University run such a brokering service for prototyping feature-based precision machined parts, which they set up in collaboration with the NCMS Rapid Response Manufacturing (RRM) project. Some brokers specialize in custom applications, making experimental services available over the Internet and eliminating technology transfer bottlenecks.

The AIMS infrastructure stimulates not just brokers, but many other third-party manufacturing support and service businesses: automated CAD format conversion, process planning, scheduling, materials handling and so forth are all now available on-line from a variety of sources. Most are entrepreneurial businesses that will create many new information services jobs.

Software toolkits and libraries, available over the network, make it fast and easy for developers to bring up new manufacturing support services. The toolkits transform manufacturing applications into mail- and hypertext-enabled network services that conform to Internet and AIMS standards. The software libraries contain validated modules with standardized interfaces for common manufacturing functions. Some of the modules are public domain, others can be purchased or even used over the network on a fee for service basis. Developers can thus focus on core elements of their application, without having to recode, redocument and retest everything from scratch. After the new system has been integrated and tested, it too can be "published" for others to build on. The advantages of reusable software are widely known in the object-oriented programming community. AIMS contribution is applying the concept on a national scale to manufacturing applications, resulting in 80% reductions in development time and cost.

The above advances in information infrastructure go hand in hand with advances in manufacturing technology and business processes at agile production sites. To keep up with the volume of bid requests generated by national brokers, job shops rely on automated costing and process planning services available over the net. Shops also rely on brokers to expedite bids from their own suppliers and subcontractors. In many cases, these outsourced services are provided for a fee by other shops who have developed or licensed the necessary software. Job shops thus epitomize virtual companies, providing customers with as many or as few services as they desire, and frequently obtaining those services from others.

In responding to bids, and later, in performing on contracts, vendors obtain needed product specifications and technical data directly from the customer's engineering document control system. Strong security provisions prevent unauthorized access. CAD format translation services are invoked automatically when needed. The availability of such translation services on the network frees suppliers from having to maintain the same CAD systems as their customers, a real boon especially to small suppliers.

True agility requires an information infrastructure and business processes that extend uniformly through all levels of a virtual enterprise, ideally right down to the shop floor. Imagine production resources on the shop floor scheduling themselves by offering services through CCAs and bidding for jobs, just like the mini-enterprises they are. Each bid is adjusted to take into account current backlogs, setups, tooling, and available stock. A machine tool might run an automated fixture planner in preparing its bid; a precision process such as MD* might even run a detailed physical simulation.

Scheduling in such an environment exhibits the same dynamic agility as taxicab dispatching; the unit that responds fastest gets the job, and units can be added or taken out of service at any time with little effect on overall system performance. As jobs are assigned, local CCAs are updated. These changes are aggregated and reflected immediately in the corporate-level CCA that customers see. Similarly, when orders arrive, the cost and delivery commitments the customer receives are precisely those that the winning bidder tendered on the shop floor.

The agents that manage equipment also keep track of material usage, reordering from stock as required. The stockroom agent, in turn, keeps track of inventory and reorders from the supplier or issues an RFQ, initiating yet another bidding process. The power of AIMS comes from its potential for linking all these processes together, expediting information up and down a supply chain, and throughout every organization along the way. The bottom line is that five years from now, parts that currently take months to prototype will routinely be turned around in a few days.

3. Elements of AIMS

AIMS' infrastructure must encompass business processes, information technology, and manufacturing technology. Agility cannot be achieved by treating these factors independently. Applying computer technology to old mass-production processes, for example, often has the undesired effect of inhibiting communication across software tool boundaries. Traditional approaches to integration, such as those involving large shared databases, do not work either; such systems are notoriously brittle and therefore difficult to extend and maintain.

3.1 Business Process

Today, establishing relations with new suppliers can take months, because everything from terms and conditions to CAD formats must be negotiated, and the suppliers' competence must be validated. The AIMS consortium must join with trade associations (e.g. NIST, AIA, NCMS) to standardize business practices and certify suppliers that adhere to them. Electronic commerce cannot function effectively while individual companies have idiosyncratic trade agreements, vendor qualification processes, part description, and the like, as these will undermine all benefits of advanced information and manufacturing technologies. It is essential that specific solutions to streamlining and standardizing business transactions be a part of an agile infrastructure.

One way that AIMS will alleviate this problem while also defining the business processes for the AIMS network is by defining the "virtual company." This is a generic strawman (model) of a company that contains all essential business attributes. The model is composed of the following elements:

- **Standardized trade agreements**

  Standardized trade agreement will preclude the arduous task of negotiation and legal dialogue that generally precede collaboration among companies. A tremendous savings in time and money can be realized if potential business partners can simply select from a standardized library of agreements.

- **Prequalified sourcing**

  Traditionally, selecting suppliers has been a balancing act between cost, and risk. Prequalification of the supplier network, via a standard certification process, will remove the uncertainty and risk. Metrics and benchmarking for agility will play a critical role in this.

- **Predefined protocols**

  Predefined protocols for information access, negotiation, ordering, payment, and closure are all necessary elements of an agile enterprise.

- **Standard forms and part descriptions**

  Another barrier comes in the form of widely varying paperwork associated with a business transaction. Simplified, uniform electronic forms, part-numbering, and part-descriptions will further reduce the overhead and delays.

- **Standard cost library**

  Standard costs for services and parts, based on a supplier's credentials, agility index, and quality grade should make vendor comparisons easier and quicker.

- **Compatible data exchange formats**

  Compatible data exchange formats for part geometry, process description, fixturing, tolerances, etc. are yet to be defined. (AIMS will use existing standards initially—e.g. PDES/STEP—and incorporate translation services eventually to overcome this challenge.)

Companies that want to offer services through the AIMS network will be expected to adopt this virtual company model, at least for their AIMS transactions.

Aside from the virtual company model, that streamlines and standardizes the operating procedures within the virtual enterprise, there are other deep issues on needs to address.

First, a method of qualifying and quantifying the agility of a service is important. A comprehensive benchmarking effort will continue throughout the program to establish baseline performance measurements. An alternative method for making the make-or-buy decisions for companies, for instance, is a direct outcome of this activity. Eventually this will be used to categorize the production services by the "agility-rating" indices within the virtual enterprise.

Second, procurement and contract acquisition procedures should be revised to accommodate the alternatives that the AIMS paradigm will offer. A seamless interaction between companies can occur only if legal and bureaucratic red tape do not obstruct the flow of events. AIMS can only hope to provide precedents in this area. More comprehensive undertakings must follow at each company to streamline the business procedures and eliminate unnecessary bureaucratic and legal barriers.

Finally, the most effective way to bring in new member companies of all sizes and types will be established for a systematic growth and technology diffusion plan. AIMS will generate the documents, toolkits, and support mechanisms to facilitate the expansion of the AIMS network.

3.2 Information Technology

This section considers the scenarios in Section 2.1 from an information technology perspective. Specifically, we discuss the requirements, our approach, and an implementation plan.

Requirements

The AIMS infrastructure is driven by three strategic requirements:

- it is the nucleus of a national infrastructure for Agile Manufacturing (i.e., a prototype of Factory America Net) [7].
- it must also support agility on the shop floor.
- at both levels, it must co-exist with legacy systems and support a graceful migration path from current industry practice to agile production.

These strategic requirements lead to the following functional ones:

- openness - reliance on published and widely implemented interface protocols so that anyone can use and offer services through AIMS, including services that enhance the infrastructure itself.
- scalability - the ability to access services across the shop floor or around the world using the same protocols.
- extensibility and graceful degradation - services can be added, removed or substituted at any time, with incremental changes in performance.
- compatibility with legacy systems through encapsulation.

Approach

AIMS fulfills the above requirements by using the Internet to access agile production services. The top-level architecture of AIMS is a loosely coupled collection of client and server agents. The servers encapsulate manufacturing resources and applications, and make them available as network services. The client agents make these services easy to use. Some servers play the role of intermediaries, providing directory, brokering, advertising, query processing, and similar services. (See Figure 3.) The agents communicate via structured messages that are readable by people and computers; messages are sent using ordinary Internet e-mail and other TCP/IP transport services. An agent-based architecture was selected because 1) it is scalable simply by plugging in new services and intermediaries, and 2) it gives each participating organization the

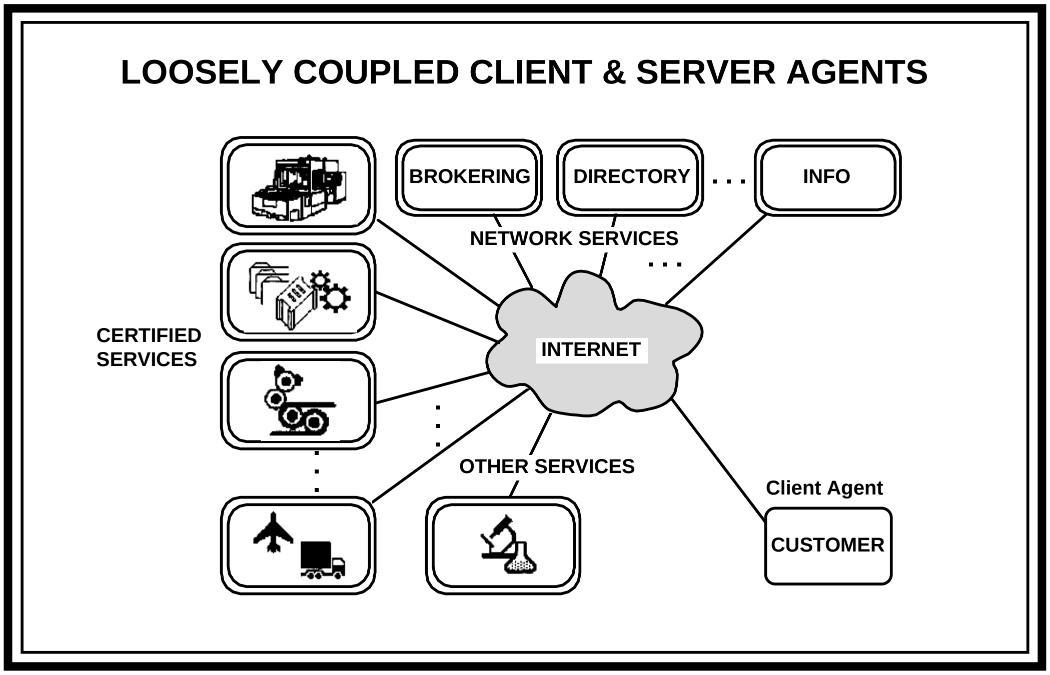

Figure 3. Network services (client's perspective).

flexibility to run whatever internal systems they wish, yet still interoperate with other members of the AIMS consortium.

AIMS builds on a reference architecture being developed by EIT, Lockheed and Stanford for ARPA's MADE program. The MADE architecture starts with emerging Internet standards for multimedia documents, hypertext and information retrieval, and extends them with advanced services that support engineering teams and electronic commerce. AIMS provides a further level of specialization, defining the interfaces, protocols and standards for fabrication services, brokers, and shop floor manufacturing applications such as process planning and scheduling. An ongoing consensus-based standards process, modeled after Internet RFC's will ensure the orderly evolution of the AIMS architecture, and its compatibility with mainstream Internet and MADE developments.

The MADE reference architecture, shown in Figure 4, has three layers: network, services and applications. At the network level, the architecture defines the data formats and communication protocols that enable clients and applications to exchange information and services. Wherever possible, MADE builds on existing Internet standards (MIME, HTML, Z39.50, NNTP, KQML etc.), extending and integrating them when necessary through the IETF's RFC process.

The services layer is a middle layer of reusable building blocks and advanced runtime services that facilitate the development and use of end-user applications. Today's Internet is used largely for basic services such as e-mail, FTP, telnet, and news. These services must be enhanced to support applications in domains such as engineering, manufacturing and electronic commerce. E-commerce users, for example, have a right to expect directories of people and services, privacy-enhanced, multimedia e-mail, authentication and access control, format translation, and payment facilities. Other mid-level services support federated systems, multimedia document sharing, real-time collaboration, and software development. Much of this middleware is under development by

ARPA contractors, including EIT, Lockheed, and MCC, and is expected to be available as public domain software in time for AIMS. What is not available will be developed by AIMS and contributed to the MADE community.

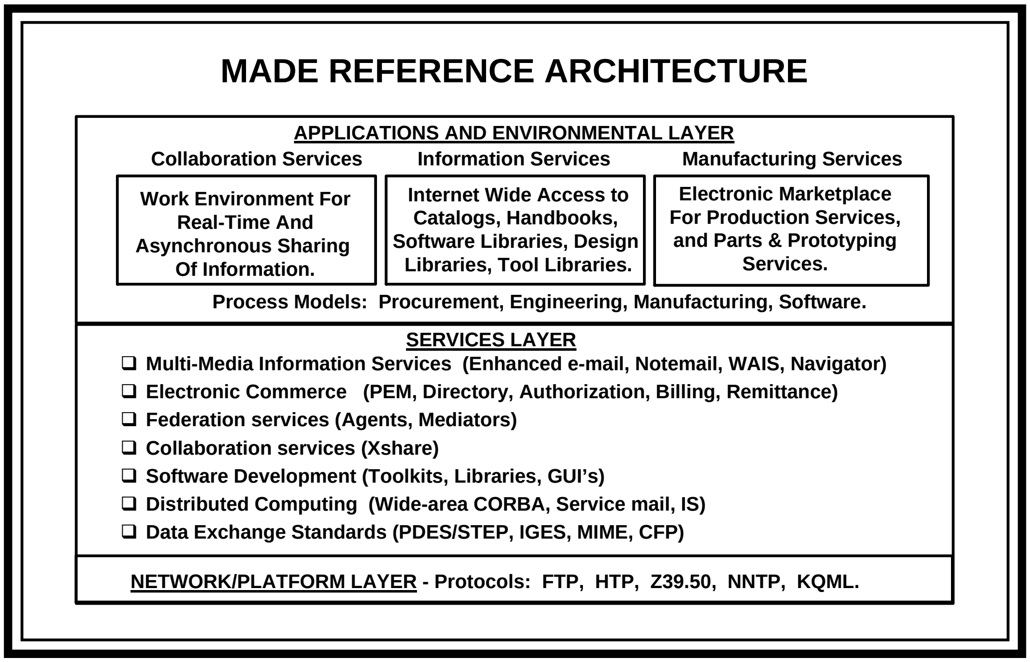

Figure 4. MADE reference architecture.

The applications layer focuses on applications and services from the point of view of how they are consumed and used. It includes several top level environments, such as one for collaborative engineering on the Internet, and another for electronic commerce. It also includes the common process models that enable such environments to work across company boundaries. AIMS will contribute to MADE a new top level environment -- for Agile Production. This environment will define stable interface standards, protocols and process models for common manufacturing functions. For example, all AIMS fabrication services respond in a consistent way to queries about their capabilities, costs and availability, requests for quotes and design critiques, placement and status of orders, and so forth.

AIMS is not alone in affiliating with MADE. Over 35 leaders in the Agile Manufacturing community have made a commitment to develop engineering and manufacturing applications around this infrastructure. The community's rationale is that it makes far more sense to build on and use each other's services, than to squander resources on creating redundant and incompatible infrastructures. An immediate dividend is that all of AIMS' end-user services are available immediately to participants in these other projects, and vice versa.

Software Development/Toolkits

An integral part of the MADE infrastructure are software toolkits—server toolkits that make it easy to offer manufacturing services over the Internet, client toolkits that make the services easy to use, and mediator toolkits that make them easy to find. Here, we briefly describe the major MADE toolkits; below, in section 4, we discuss how they will be used in implementing AIMS.

Server Toolkits

- *ServiceMail:* a toolkit that transforms UNIX applications into mail-enabled Internet services. Through ServiceMail, engineers can access design libraries, run simulations on supercomputers, and order parts or machining services, all via e-mail. Services are requested by filling out electronic forms (e.g., purchase orders). The forms are then bundled with design files and other relevant data in a single multimedia (MIME) mail envelope. At the receiving end, incoming messages are decomposed and each component automatically routed to the appropriate person or program. The responses (invoices, simulations, etc.) are then re-assembled and returned to the user in another multimedia mail message. ServiceMail handles all the details such as mail transport, command parsing, and scripting.

  ServiceMail is currently in use at over 50 university and companies, and provides a variety of Internet services including fabrication (machined parts), simulation (semiconductor processes), and parts catalogs (gears). Future releases will support access control, payment, and electronic forms. They will also include ServicePacks containing canned scripts and commands for transforming common engineering applications (e.g., product data management systems, simulators) into network services.

- *Internet Services Toolkit (IST):* The IS Toolkit, currently under development at EIT, generalizes Servicemail to accommodate interactive protocols such as IP, HTTP, and NNTP in addition to e-mail. The IS toolkit supports the abstraction of agents that encapsulate legacy applications, enabling them to interact with other AIMS services using standard messages.

- *Public Disc:* a commercial Internet service that distributes information via email. Based on ServiceMail, it supports multimedia data, access control and payment. We anticipate using Public Disc in AIMS to distribute datasheets, catalogs, literature, CAD models, software and other information for smaller job shops who might prefer to outsource this function.

- *Distributed Information Service (DIS):* an information sharing substrate that enables loosely coupled client-server applications to share their object-oriented models over the Internet. A shared model typically remains physically under the control of the application that created it; a persistent object is created in DIS that serves as a reference pointer or "handle." Besides a persistent object store, DIS includes a name server, notification mechanism, and other basic services needed for distributed object computing. DIS is compatible with OMG's CORBA, extending it for loosely coupled environments through features such as e-mail transport and access control across trust boundaries.

Client Toolkits

- *Information Navigator* — a customizable "point and click" graphical interface to MADE information and services. Internet services are notoriously difficult to locate and use. The Internet Navigator provides icons for frequently used services. Once an icon is selected, the navigator selects the appropriate protocol and opens a connection. Users interact with services via menus and pop-up electronic forms. Outputs (text, graphics, audio, and video) are displayed automatically by invoking the right presentation tools. When a service references other information resources, these resources can be accessed with similar transparency, regardless of whether they reside on the same machine or half-way around the globe. The Internet Navigator is based on popular new Internet standards for Hypertext (HTML) and multimedia (MIME), and will be available for Unix, PC, and Mac platforms.

- *NoteMail* — a tool for creating, viewing, and sharing multimedia engineering documents in a network environment. It combines the functions of an engineering notebook, hypermedia browser and authoring environment, mail tool, and file application manager.
- *X-Share* — a set of programs that provide real-time conferencing and application sharing over the Internet. Specifically they provide interactive audio, video, text, and graphics connections among participants as well as the ability to jointly run applications. The audio and video connections will support multi-participant conferences using the new MBONE [3] Internet multicast protocols. The text service also supports multi-participant discussions, in the style of Internet Relay Chat. The graphics connection provides a shared screen with transparent overlays on which participants can sketch and draw using distinctive colors. The text, graphics and application sharing services are based on XTV [1], a public domain software package for sharing X window-based applications.

Mediator Toolkits

Mediators are customizable agents that function as intermediaries between clients and servers. They enable applications to locate needed services, connect to them, and communicate despite differences in data and knowledge formats. Mediators combine the functions of a back-to-back client and server, appearing as servers to end users and as clients to service providers. Mediators can thus invoke the services of other mediators. Mediators are essential for creating large-scale federated systems using the ServiceMail and IS Toolkits.

Building on the results from Lockheed's SHADE project [6], AIMS will provide reference implementations for the following mediation services, which are needed for the machining pilot.

- directory services
- mail forwarding agents
- brokers that post RFQs, accept bids, make awards.
- CAD format translators
- aggregators that combine multiple orders into a single service request.
- information agents (also called facilitators) that route requests for part information to appropriate engineering databases, arranging for format translation services if required.
- user agents that can be programmed by end users to automate routine workflow tasks such as forwarding mail or invoking a program whenever a particular program arrives.

Anyone interested is offering value-added mediation services to the MADE and agile manufacturing communities will be able to do so by customizing these reference implementations.

3.3 Manufacturing Technology

Information technology alone does not guarantee responsiveness, either at the enterprise level or at the site-facility level. Manufacturing process-related impediments to agility must also be eliminated.

For small-lot, rapid response machining services, machine setup and changeover times are recognized as the major cost drivers. The AIMS partners have agreed to work jointly on developing technology that will minimize setup and changeover times. Significant opportunities for improvement have been identified in five areas: fixture configuration, part setup, part and process verification, cutting tool management, and simplified shop documentation.

The design and fabrication of part-specific fixturing represents a significant fraction of production costs and cycle times. The AIMS partners will collaborate on the use of modular fixturing and explore the feasibility of hybrid fixtures. These fixtures combine unique disposable features with reusable modular components.

The part setup problem is closely related to fixturing. Setup involves removing existing fixtures, installing new ones, loading the proper cutting tools, and verifying that everything is in order—all time-consuming operations. In small lot production, setup can account for the majority of the direct labor content and cycle time of a job. The AIMS partners propose to benchmark the setup process and explore means of neutralizing its impact.

Part and process verification, the methodical in-process inspection of parts and associated evaluation of the fabrication process, also contributes significantly to cycle times and costs. Methods for evaluating the likelihood of producing a good part prior to actual production, combined with methods for examining and controlling the process statistically and dynamically during production are essential if we are to thrive in a changing environment [8,11]. To ameliorate these overheads, AIMS will explore techniques such as part-program simulation, on-machine probing, statistical performance assessment, and the use of coordinate measuring machines.

Cutting tool management is critical. The diverse part families that AIMS embraces require a vast array of cutting tools. The large number of tools complicates part production in many ways. The AIMS partners will jointly examine the feasibility of standardizing on a limited set of cutting tools, to reduce programming and setup times, and tooling inventories.

Simplified shop documentation is essential for a dual-use, rapid response production facility, especially where small lots are involved. We are developing a methodology for determining and capturing only that information which is essential for producing a specific part.

The above issues, while specific to machining, are representative of the process-related problems that will have to be solved in every manufacturing domain to achieve agility.

4. Implementation Strategy

AIMS will follow an incremental implementation strategy that minimizes investment risks and disruptions to ongoing production. The plan is to get a baseline AIMS service up and running as rapidly as possible, and then continuously upgrade it over the life of the project. The initial prototype will be limited to producing simple prismatic parts at the five AIMS sites, using whatever manual or computer-assisted processes and systems currently exist at each site. All interactions will take place directly between customers and providers without intervening brokers. Subsequent incremental improvements will increase the degree of automation, the reliance on electronic (vs. paper) transactions, the complexity of parts, the variety of processes, the number of provider sites, and the use of 3rd party support services.

Precision machining was selected as the initial domain because it is a common and well understood process. Attention can thus be focused on the information and business aspects of the infrastructure, which are new and process independent. Once the machining service is in routine operation, the AIMS infrastructure will be opened to other production domains. Planned services include support for plastic part production, welding and laser cutting, stereolithography, and chemical processing.

A four phase plan has been devised to transition gracefully from a handful of isolated job shops to a nationwide agile production network.

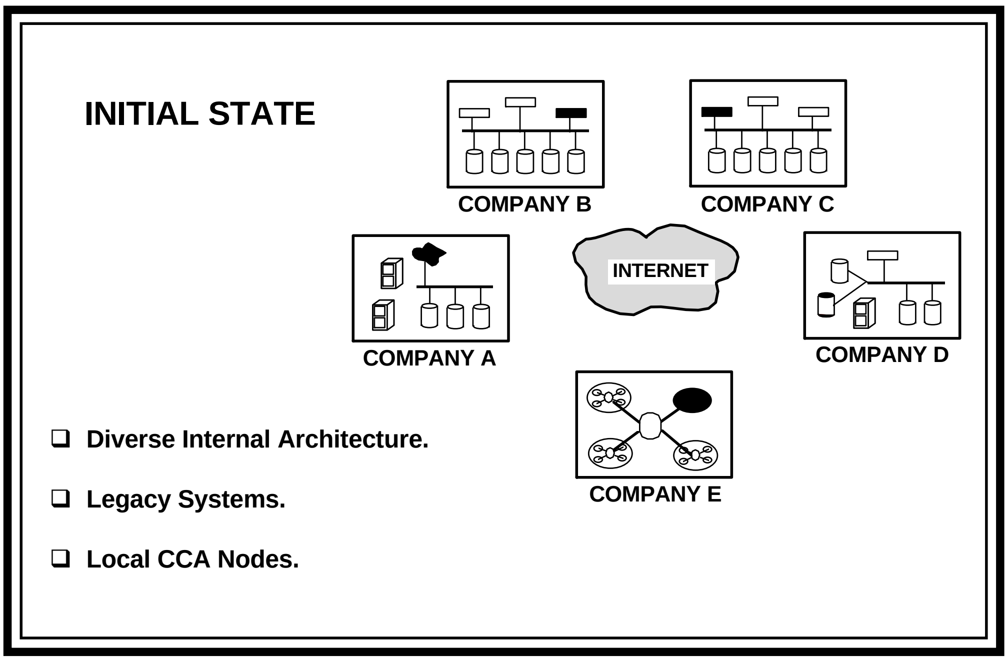

Figure 5. Initial state of AIMS.

Phase 1: Baseline AIMS service

The initial phase, lasting approximately 9 months, will establish a baseline AIMS network that will provide parts via e-mail from the five pilot sites. The AIMS team must first agree on a "plug-compatible" network interface common to all sites. This interface will define a set of standard messages for requesting information and services that all sites will handle in a uniform way. An example of such an interface is shown in Table 1. In parallel, the AIMS team will construct the "Virtual Company" business model for the AIMS enterprise. The model standardizes data exchange formats, transaction protocols, trade agreements, accounting practices, and the procurement process.

Each site will be responsible for developing applications that respond to the standard messages by making appropriate calls on its legacy manufacturing and business systems. For example, each site will need an application that creates, on demand, a current CCA (Capabilities/Cost/Availability) datasheet. As described in the scenario, these datasheets resemble pages in a Thomas Register, complete with tables, graphics and pictures. However, unlike a printed catalog, the CCA data can reflect up to the minute conditions on the shop floor by inserting them just before mailing via live links from the shop's MIS, production control, and SQA computer systems.

The applications, in turn, are transformed into network services using the Servicemail toolkit described in section 3.2. When a service request arrives via Internet email, it is parsed by ServiceMail and forwarded automatically to the appropriate application. E-mail was chosen as the transport layer for the baseline AIMS network because it is familiar, widely available, and provides network access even through firewalls. ServiceMail enhances traditional e-mail functionality in two essential ways: first, it supports MIME, the emerging Internet standard for multimedia mail, enabling messages to contain large amounts of data in multiple formats—CAD drawings and 3-D models, pictures of parts, part specifications, order forms, and so forth; second, it provides encryption to protect sensitive data.

Standard email addresses will be established at each site for invoking common services: "info" – provide a menu of available services; "order" – place an order, "status" – check the status of an order, and so forth. Electronic forms will be provided for requesting services through these addresses. The forms will include SGML tags that enable them to be read and understood by a program or a person, depending on the stage of automation. An email directory of people, sites, and services will be established to facilitate communication.

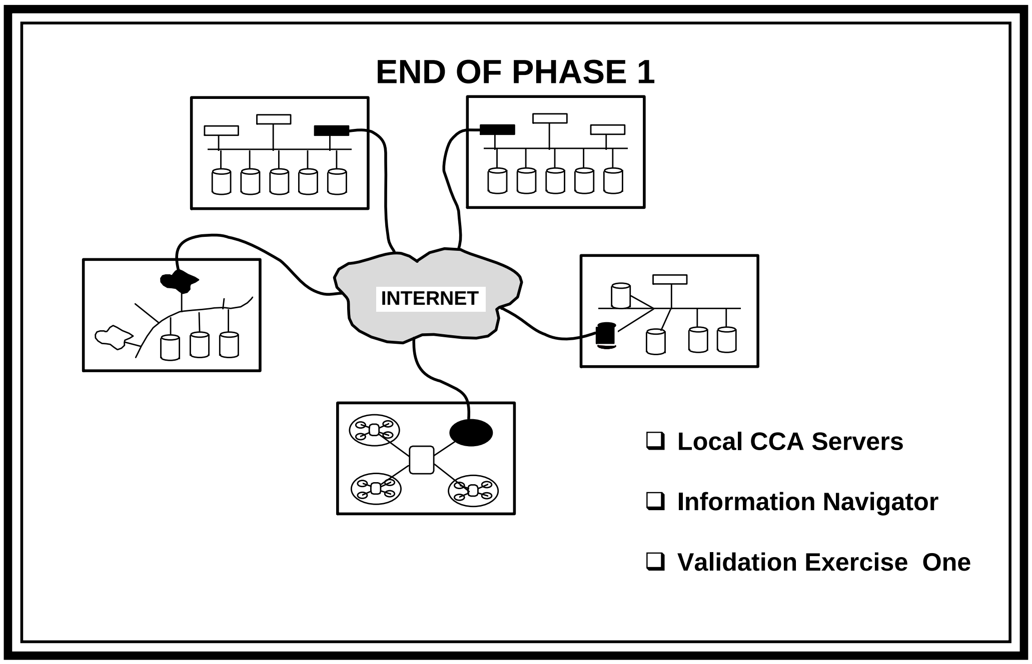

Figure 6. Baseline AIMS network.

Each pilot site will install multimedia (MIME) mail clients, so that its personnel can interact easily with ServiceMail services, both locally and at remote sites. Commercial MIME e-mail packages have been announced for all major platforms (e.g., Windows, Macintosh, Unix/X). These commercial packages will be customized by adding pull down menus containing the directory of AIMS e-mail addresses and the list of standard service requests. Design and production engineers will be able to obtain CCA datasheets, solicit quotes and place orders from any AIMS' production site on the Internet.

Finally, desktop video collaboration capabilities will be installed at each member site. The installation, which involves a plug-in video board for a PC or workstation, a TV camera, and public domain software support for Internet IP multicast protocols [3], should be available at a cost comparable to a PC. Information sharing tools such as Notemail and Xshare will further enrich the collaboration process. Video conferencing will be used initially to facilitate the collaborative development of AIMS services. Once AIMS is operational, video conferencing will be used to resolve problems arising during part manufacturing.

Figure 6 depicts the baseline AIMS network at the end of Phase 1. Phase 1, like all subsequent phases, will culminate in a formal validation exercise. Unlike a one-time demo, the purpose of these exercises is to certify the services that each site will provide on a production basis through AIMS.

Phase 2: Scaling up

The second phase, lasting about 6 months, will transform the baseline AIMS network into a scalable infrastructure capable of someday accommodating thousands of specialized job shops, suppliers, distributors, brokers and other third party information suppliers. Central information nodes cannot be tolerated in such an infrastructure because they are performance bottlenecks and reliability risks. A fully distributed network of suppliers, by contrast, can grow rapidly by accommodating many autonomous, specialized service providers. Each node maintains local control over its own operations and data, yet cooperates with other nodes in a self-organizing way to optimize the Nation's production resources.

We will augment e-mail access to Agile Production services with an alternative means of access via interactive hypermedia. We will also implement and operate prototypes of directory, brokering, bidding, and CAD format translation services. Such intermediaries facilitate business transactions in the electronic marketplace, just as they do in traditional markets, enabling AIMS to scale up to large numbers of agile production services. We will also publish the interface standards for directories and brokers so that third-party providers can offer services that are specialized for niche markets. A directory can include virtually any information about manufacturing capabilities and application services that a company cares to provide, such as pictures of equipment and sample workpieces, selection guides to tooling and fixturing, even executable process models. Anyone will be able to offer their services through this infrastructure by listing their capabilities with the appropriate directories and brokers. They can then immediately begin bidding for work and responding to service requests.

Hypermedia access will be provided using the Internet Navigator client and the IST server described in section 3.2. Through the Internet Navigator, the AIMS infrastructure will look like an integrated web of information and services spanning the entire community. Users will traverse this web using intuitive hypertext interfaces and electronic forms, relying on the directory and brokering services to help them locate needed services. Authorized users will be able seamlessly to access a site's internal information bases in the same intuitive fashion. Simplifying the process of finding needed services, and eliminating the need to learn idiosyncratic graphical interfaces and login procedures before using them, are the keys to spontaneous and widespread electronic commerce on the Internet.

Each AIMS site will upgrade their ServiceMail server to IST, which supports hypertext (HTTP) in addition to E-mail. The IST server will provide interactive access to CCA datasheets and other information services. As discussed in the scenario, every service will offer a hypertext menu like the one shown in Figure 2.4. Selecting any item leads to further interactive possibilities such as an electronic form to complete, or a multimedia presentation.

The Navigator and Directory services will utilize emerging standards for wide-area information retrieval (Z39.50, WAIS, HTTP). This design choice makes information on AIMS services widely available through public domain browsers. It also encourages researchers and third party software vendors to develop new and better applications for this market. The above standards are being extended under the MADE program to support service invocation, access control and authentication, and payment.

The prototype brokering and bidding service will match buyers and sellers of fabrication services and other commodities. Customers and providers will use semi-formal E-mail to post and retrieve messages on a bulletin board that is organized into appropriate commercial categories. Buyers will post RFQ messages containing explicit attributes of a desired product or service (e.g., "product class or category," "bid closing date," "required delivery date," "quantity"), as well as any associated unstructured data, such as drawings. Sellers will send complementary messages requesting all RFQ's satisfying specified attribute filters. (Sellers can also post standing orders requesting notification whenever a suitable RFQ is posted.) Sellers could then submit quotes in response to the retrieved RFQs. Winning bids for an RFQ can be announced to all responders, at the buyer's option.

CAD format translation is needed in a scaled-up system to handle the inevitable local exceptions to the AIMS virtual enterprise standards. We will take existing translators developed for internal use by various AIMS team members and transform them into network services using ServiceMail.

A final objective in Phase 2 is to integrate AIMS client software directly into CAD and CAM

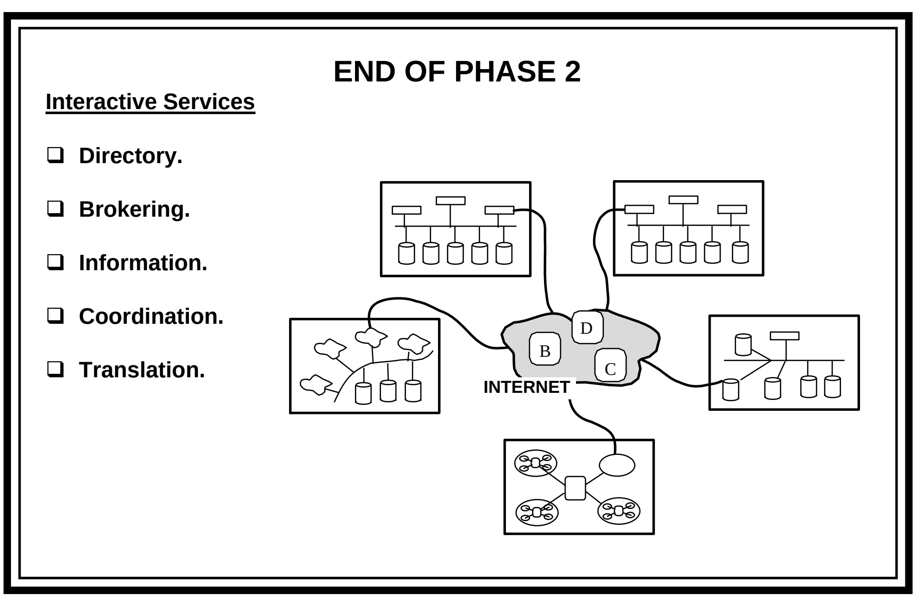

Figure 7. AIMS Infrastructure at the end of Phase 2.

environments. An engineer, working at a CAD system, should be able to pull down a menu and send a design directly to a fabrication service, requesting a preliminary cost estimate, a DFM analysis, a production schedule and other services listed in Table 1. In phase 3, AIMS team members will begin offering (semi)automated services for responding rapidly to such requests.

In parallel with these improvements to the information infrastructure, the AIMS team will continue refining the Virtual Company business model. Suppliers and other potential members will be invited to participate in the refinement and further planning activities. In addition, team members will be working on the manufacturing technology issues identified in section 3.3, in collaboration with manufacturing researchers at Stanford and Berkeley.

Phase 3: Automation

Until now, the AIMS infrastructure has primarily helped people interact with Agile Production services. However, in a full virtual company scenario, heterogeneous computer systems (not just people) must understand and react to each other. Phase 3, beginning in month 15 and continuing through the end of the project in month 36, will take the first steps toward extending the AIMS architecture for such autonomous operation. The enhanced architecture will be used initially for shop floor control at Lockheed. It will also be deployed in a few limited inter-enterprise experiments.

The Phase 3 AIMS system will feature an agent-based federation architecture [5, 2], in which information agents serve as interfaces to programs, databases and frameworks. The agents will exchange information and services over the Internet using an extensible Common Manufacturing Language (CML), designed specifically for interacting with Agile Production and brokering services. The CML message will be encapsulated in a MIME wrapper, and then passed between agents using a simple command language (with commands like Tell, Ask, and Forward). Special agents, known as matchmakers or facilitators, route information and requests to the appropriate agents. To ensure openness, AIMS agents will be layered on top of industry-standard interoperation platforms such as DCE and CORBA.

User agents are also provided as part of the AIMS Phase 3 architecture. Such agents can be programmed by end-users to respond to specified events (e.g., an incoming agent message or e-form) with simple actions (e.g., starting up a program, or notifying another agent). They are thus ideal for automating routine workflow tasks that previously were performed manually. User agents can be programmed, for instance, to query brokers, locate services in directories, and monitor equipment or inventory levels.

We will implement a few limited demonstrations that illustrate the potential of AIMS' federation services in virtual corporations. Here are just a few of the possibilities.

- A purchasing agent can locate suitable vendors in a directory, then negotiate with the vendor's agents to obtain the best price or delivery for a part. (In preparing its bid, the vendor's agent might take into account current setups, tooling, and available stock, as well as negotiate with its own suppliers.)
- Manufacturing control agents at cooperating vendors can coordinate production schedules and dynamically balance loads.
- Engineering data base agents can notify each other of design changes that affect other members of a multi-company design team.
- Engineering and product data can be routed automatically through appropriate format translation services to effect a seamless transition of CAD data through a supply chain.

AIMS team members will select a few such experiments that are most relevant to their business needs.

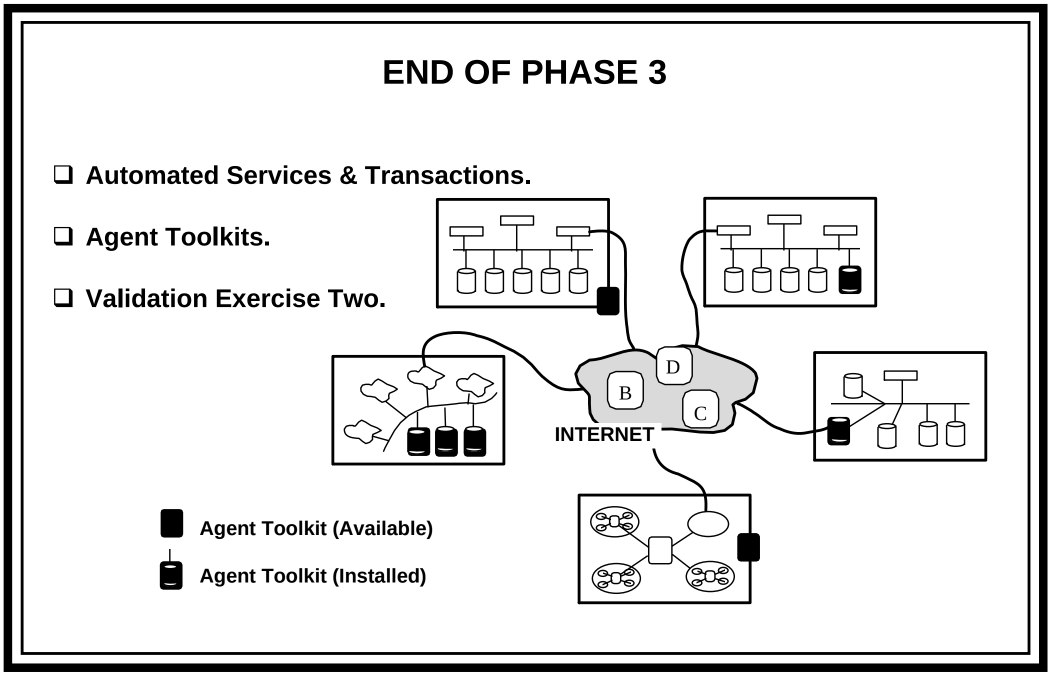

Figure 8. AIMS infrastructure at the end of Phase 3.

At least one company will experiment with using AIMS agents internally to implement a modular shop floor control system. Each agent models one element of a flexible factory: a piece of equipment, a workcell, a production line, and so forth. It encapsulates all the application software, parameters and states associated with its component, enabling outside agents to interact with that component through the standardized AIMS interface shown in Table 1. When a new piece of equipment (or workcell) is installed, its agent is simply "plugged in" to the AIMS infrastructure. The agent announces its presence to the other agents, and thereafter, it is ready to respond to requests for information and services (e.g., provide its CCA datasheet), and to bid for jobs itself. Systems structured in this way are inherently open, scalable, and reliable: Capabilities can be brought on line or removed at any time with only incremental impact on production. They are also well suited to the short-run nature of agile production where schedules must adapt instantaneously to changes in demand.

The company will also experiment with using programmable user agents to automate workflow on the shop floor as well as to integrate the shop floor with other enterprise activities. For example, someone might program a shop-level agent to aggregate CCA data from multiple workcells before making the data available to customers. A shop supervisor might task a user agent to watch inventory levels and automatically forward reorders to a supplier. Interestingly, the supplier may or may not have installed an automated agent to field such requests. Because

AIMS agents deal interchangeably with both people and other agents, automation can proceed one job at a time, providing a graceful migration path from today's manual systems.

If these experimental implementation(s) on the shop floor prove successful, the technology will be offered to the other partners.

Phase 4: Outreach

The objectives during this final phase are to: 1) extend the benefits of AIMS to a much larger community of manufacturing information and service providers; and 2) extend the scope of AIMS beyond production to integrated product and process design. Phase 4 will begin in month 24, and overlap with Phase 3 during the third year of AIMS.

To help bring additional service providers on-line, AIMS will distribute commercially supported versions of the Servicemail and IS Toolkits. To stimulate new third-party services we will release generic broker and directory service agents that others can customize to accommodate specific markets. Public Disc service will be available to smaller job shops to disseminate their service information. To encourage more designers to try AIMS, we will offer a MOSIS-style brokered acquisition service through Stanford and Berkeley. The first users of such a system will be students, who will use it to do rapid prototyping for their design classes. Finally, we will install gateways between AIMS and other manufacturing infrastructures (e.g., EINet, MAEC, ETDAM), so we can make use of each other's services.

The second thrust in Phase 4 will broaden the goals of AIMS beyond production, to support other stages of collaborative product development. Some of the necessary elements already exist, such as the video conferencing facilities (phase 1), the CAD clients (phase 2) and the federated systems architecture (phase 3). We will combine these with advanced Internet engineering services currently under development at EIT, Lockheed, Stanford, UC Berkeley and other MADE/DICE sites [5, 10, 9]. The focus will be on network support for concurrent engineering and integrated product/process design.

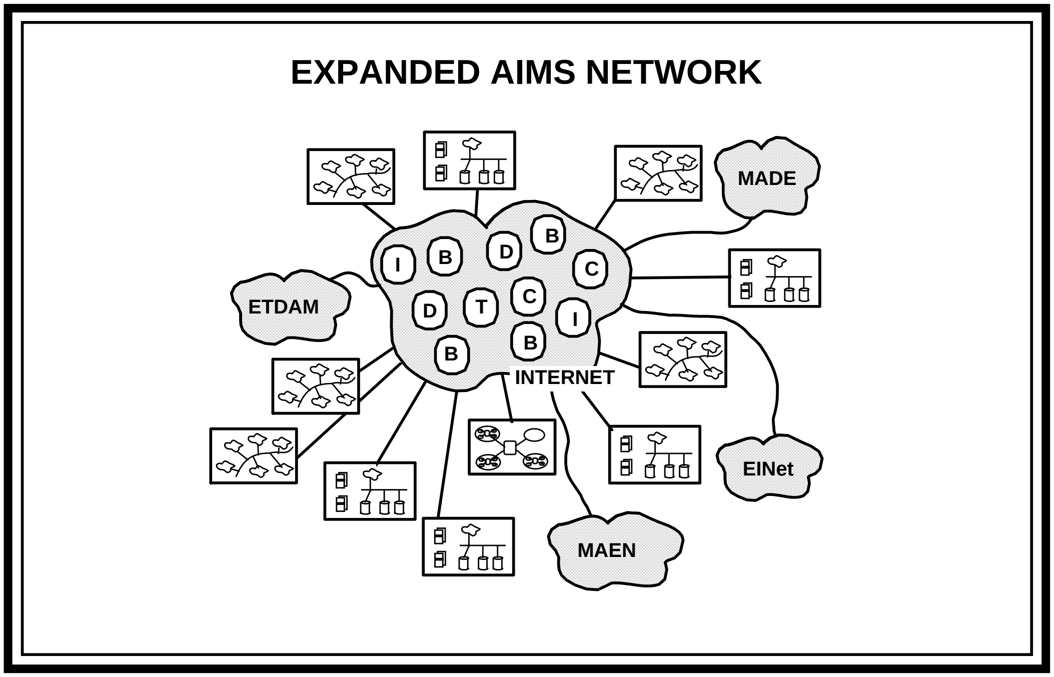

Figure 9. Expanded AIMS Network

Anticipated services include:

- Distributed product information management integrating the product data maintained by all organizations involved in a product's lifecycle, to deal consistently with change notification, versioning, configuration management, constraint violations, etc.
- Distributed process management—keeping track of schedules and commitments; managing signoff processes across organizations, so that the right procedures are performed before a design or part is released.
- Engineering groupware—facilitating communication among members of a design team, using multimedia mail and real time conferencing that combines audio/video with shared tools and design data. (A key requirement here is the need for standards and/or format translators that permit interoperation across heterogeneous platforms.)

As these services are clearly beyond the original scope of AIMS, they will be pursued only insofar as resources allow.

5. Discussion

Reductions in the defense budget are causing deep and permanent downsizing in the defense industry, to the point of threatening core capabilities of critical defense manufacturers. At the same time, many manufacturers in the commercial sector are downsizing deeply to meet fierce competition and adjust to a sluggish world economy, also threatening core competencies. While critical capabilities are being lost, new requirements for faster response and greater production flexibility are emerging in both the defense and commercial markets.

These trends represent a serious threat to the US defense manufacturing base. To survive, defense companies must:

- Protect skilled workers in core-competencies,
- Strengthen core competencies and expand markets for them, and
- Cease to invest in marginal ones.

At the same time they must find a way to maintain a fully responsive internal production capability, while improving overall production cost, time, quality, and risk.

To satisfy these objectives, defense manufacturers must (1) develop new delivery channels for their production core competencies, and (2) develop the ability to quickly and efficiently outsource abandoned capabilities to manufacturers with complementary core competencies.

The AIMS project seeks to address these needs by creating a virtual production enterprise: a national network of dual-use, agile production facilities, that minimizes the time and costs involved in out-sourcing work that others can do better. The outcome is a stable environment where a reduced defense industrial base can remain robust. Similar benefits extend to other types of manufacturing, allowing more efficient use of capabilities and faster prototyping and production turnaround.

5.1 Transformation of the Industrial Base

A critical mass of participating companies is necessary to overcome the inertia of the old paradigm, and to initiate the transformation in technology, business, and manufacturing process described earlier. The AIMS consortium represents this critical mass.

At the end of the 24-month pilot program, AIMS will have established the following components:

- Working prototype of a virtual enterprise
- Proven open, scalable information architecture
- Templates for agile business transactions over the Internet
- Fundamental benchmarking procedures and metrics for certifying and categorizing suppliers
- Validated method for building an agile production facility.

In addition, the AIMS consortium will constitute an established base of network users, ready to diffuse this capability to their customers and suppliers. The combined market clout of the AIMS team should provide powerful incentives for smaller companies to connect to the AIMS infrastructure. Potential buyers will join for access to the network of certified suppliers. Suppliers will join to tap into the growing on-line market for their services. Affordable software module (toolkits), documented, straightforward procedures, and consulting support will facilitate this membership growth.

AIMS will also leverage other compatible agile-infrastructure projects for future expansion. NCMS, for example, is expected to play a key role in the proliferation of the AIMS network. As part of its internal charter, NCMS is forming a network of teaching factories that also include hundreds of small and medium sized companies. AIMS and NCMS are committed to creating a compatible infrastructure that will transform these companies into users and providers of AIMS service.

For the sustained, healthy growth of AIMS, a method of qualifying and quantifying the agility of production services is essential. A comprehensive benchmarking process must be developed to establish the baseline cost and performance measurements. The benchmarks will provide companies with a rational basis for their make-or-buy decisions. Continuous, competitive benchmarking will establish a pervasive advertising and pruning mechanism over the network, contributing to a vital, competitive manufacturing infrastructure and national economy.

Creation of New Firms

The extent of redundant capacities and continued reduction of defense budgets make further downsizing of defense companies inevitable. However, AIMS can help ensure that the downsizing affects only the redundant and marginal areas, and not the areas of core competencies. AIMS can also help defense companies expand into commercial markets.

In parallel, AIMS will stimulate the creation and growth of numerous small and medium sized suppliers due to:

- Increased outsourcing by large contractors as they eliminate their marginal capabilities
- Reduced cost of doing business via CCA—including reductions in advertising, negotiating, and transaction expenses.

As more companies join, the volume and complexity of information available on the network will become enormous. Information services of all sizes and varieties will form to address the rising need, to coordinate, direct, broker, and translate information between customers and suppliers. A variety of third-party brokering services will appear, for example, to match buyers and sellers of production, engineering and other services.

Software developers will be attracted to this market to develop new tools for users and providers of AIMS services. Consulting and support business will also emerge for helping companies utilize the various resources on the network. The market potential is huge.

Such information, software and service businesses should proliferate rapidly because little startup capital is required. Basic software, documentation, and consulting for getting started will be readily available and affordable, predominantly over the network. These new businesses will stimulate the economy, generating many high-quality jobs, while enhancing the responsiveness and stability of the US industrial base.

Dual-Use

With the reductions in defense requirements and budgets, the defense industry cannot continue as before. Large overhead costs prevent defense companies from competing on the basis of their direct capabilities. "Dual use" of the defense industry is not feasible as long as a dichotomy exists between the defense and commercial sectors—in bureaucracy, contracting requirements, procurement policies, etc. The defense companies must transform quickly into much leaner, more agile providers of special capabilities. AIMS starts this transformation by

- Reducing overhead costs
- Preserving capital, while strengthening core-competencies
- Providing a profitable channel for selling excess capacities.

AIMS can help defense companies achieve the leanness required to compete in the open market. The AIMS strategy allows partners to cease investing in marginal capabilities and instead rely on outsourcing to organizations with complementary core competencies. AIMS' competitive benchmarking will prod companies to identify their core competencies and continually to evaluate and strengthen them. The AIMS network provides a channel for selling excess capacities, which in turn, will help balance and stabilize the skilled workforce, and preserve a company's investment in its core-competencies. At the same time, eliminating marginal capabilities and simplifying business processes are likely to reduce or eliminate overhead costs.

Strengthened core-competencies and reduced overheads will make defense companies viable contenders, able to compete successfully based solely on their quality, reliability, and responsiveness. This, we believe, is the only way to reverse the current trend of deep down-sizing, and the consequent loss of high-quality jobs and national industrial assets. It paves the way for a national network of agile companies, that will become the future defense industrial base.

Full Utilization of National Resources

AIMS can serve as a dissemination channel for manufacturing education and research. Universities, laboratories, and libraries can offer services through the network, and receive the full benefit of the AIMS infrastructure, including standardized protocols, data exchange formats and transactions, security, and payment.

National laboratories can offer unique services on the network. Oak Ridge National Labs, for instance, can offer micro-precision machining and inspection capabilities available at few places in the world. AIMS will create an opportunity for a network of national laboratories to link with hundreds of manufacturing and service organization, effectively contributing to the competitiveness of the US companies.

Universities and other research institutions can use AIMS for technology dissemination, beta-testing, and collaboration, by making their tools, models and applications available as network services. Access to courses, libraries and databases will form a valuable extension to commercial information services on the network.

Concluding Remarks

By the end of Phase four, we expect that AIMS will have amassed a critical mass of users and services. Both the technical and financial incentives should be in place for a rapid, self-sustained expansion of the network. Assuming other MADE-compliant infrastructure projects, such as MAEC and ETDAM, have undergone a similar maturation process, they will be ready to link up with one another. If these expectations are even partially realized, the US will have a de facto manufacturing infrastructure connecting a significant fraction of the total supplier base.

Clearly, the cost and risks associated with starting up an enterprise such as AIMS are more than one company, or one sector can bear alone. Nor can the required consensus be achieved unless the industrial, university, and government sectors join forces from the beginning. It is for this reason that the AIMS consortium was originally conceived and why we subsequently decided to propose a major defense conversion initiative. If our proposal is selected, the combined resources of the companies and the government funds should provide sufficient impetus to start the transformation of the US industrial base.

It is essential to recognize that competitiveness can no longer be assured internally. Increasingly, companies must rely on the agility of others. Manufacturers must learn to leverage the capabilities of their suppliers, partners, and even competitors to advance their own capabilities. Each company that achieves a new level of agility thus enhances the overall competitiveness of the larger manufacturing community. The ultimate objective of AIMS and its consortium members is to generate an environment in which this paradigm can proliferate.

Acknowledgment

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Appendix: Acronyms

AIC	Lockheed Artificial Intelligence Center, Palo Alto, CA.
API	Application Program Interface
APS	Agile Production Service
CCA	Capability, Cost, and Availability (data)
CORBA	Common Object Request Broker Architecture
EIT	Enterprise Integration Technologies, Inc., Palo Alto, CA.
EINet	MCC's Enterprise Integration Network
ETDAM	Enterprise Technology Deployment for Agile Machining (DOE-sponsored program)
GUI	Graphical User Interface
HTTP	Hypertext Transport Protocol
IST	Internet Services Toolkit
KQML	Knowledge Query and Manipulation Language [4]
MAEC	NCMS' Manufacturing and Education Centers
MIME	Multi-purpose Internet Mail Extensions
NCMS	National Center for Manufacturing Sciences, Ann Arbor, MI.
NII	National Information Infrastructure
RFC	Request for Comment
RFQ	Request for Quote
RRM	Rapid Response Manufacturing—NIST funded project
SHADE	Shared Dependency Engineering—ARPA funded project [6]
SQA	Statistical Quality Assurance
TCP/IP	Transfer Communication Protocol/Internet Protocol
VCI	Virtual Corporation Infrastructure
WAN	Wide Area Network
WAIS	Wide Area Information Server
WWW	World-Wide-Web

References

[1] Abdel-Wahab, H. M. and M. A. Feit 1991. *XTV: A framework for Sharing X Windows Clients in Remote Synchronous Collaboration*. Proceedings of IEEE Conference on Communications Software: Communications for Distributed Applications and Systems, Chapel Hill, NC, 159-167.

[2] Cutkosky, M., R. Engelmore, R. Fikes, T. Gruber, M. Genesereth and W. Mark 1993, January. PACT: An Experiment in Integrating Concurrent Engineering Systems. *IEEE Computer, special issue on Computer Supported Concurrent Engineering* **26**(1), 28-37.

[3] Deering, S. 1992. *Host Extensions for IP-Multicasting*. Network Working Group Request for Comments RFC 1112. Stanford University.

[4] Finin, T., Weber, Wiederhold, Genesereth, Fritzson, McGuire, McKay, Shapiro, Pelavin and Beck 1992. *Specification of the KQML Agent Communication Language. Official Document of the DARPA Knowledge Sharing Initiative's External Interfaces Working Group*. Technical Report 92-04. Enterprise Integration Technologies, Inc.

[5] Gruber, T. R., J. M. Tenenbaum and J. C. Weber 1992. *Toward a Knowledge Medium for Collaborative Product Development*. Artificial Intelligence in Design, J. S. Gero, ed., Pittsburgh, Kluwer Academic Publishers, 413-432.

[6] McGuire, J., D. Kuokka, J. Weber, J. Tenenbaum, T. Gruber and G. Olsen 1993. SHADE: Technology for Knowledge-Based Collaborative Engineering. *Journal of Concurrent Engineering: Research and Applications* , to appear.

[7] Nagel, R. and R. Dove, Principle Investigators; S. Goldman and K. Preiss, Editors. 1991. *21st Century Manufacturing Enterprise Strategy, An Industry-Led View*. Iacocca Institute, Lehigh University.

[8] Park, H. and T. Little 1992, June. Assessing Machine Performance. *American Machinist* , 39-42.

[9] Toye, G., M. Cutkosky, L. Leifer, J. Tenenbaum and J. Glicksman 1993. *SHARE: A Methodology and Environment for Collaborative Product Development*. Technical Report 1993-0420. Stanford Center for Design Research.

[10] Weber, J., B. Livezey, J. McGuire and R. Pelavin 1992. "Spreadsheet-Like Design Through Knowledge-Based Tool Integration. *International Journal of Expert Systems: Research and Applications* **5**(1).

[11] Wright, P. K., J. Hong, X. Tan, L. Pavlakos and F. B. Hansen 1992. *MOSAIC: Machine-Tool Open-System Advanced Intelligent Controller*. Proceedings of the 1992 NSF Design and Manufacturing Systems Conference, Georgia Tech, 793-798.

Overhead Presentation:
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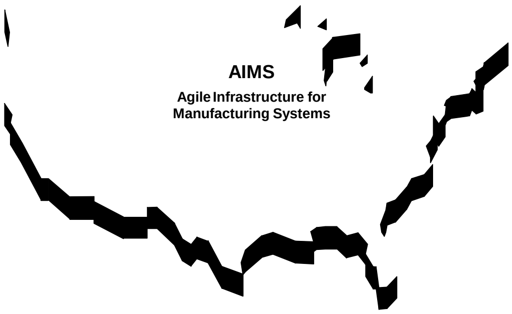
AIMS

Agile Infrastructure for
Manufacturing Systems



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AIMS TEAM

Industry Partners:

- General Motors
- Lockheed Missiles and Space Company
- Martin Marietta Electronic and Missile Systems
- Rockwell International Corporation - Rocketdyne Division
- Texas Instruments - Defense Systems and Electronics Group

Technology Diffusers:

- Martin Marietta Energy Systems (Operating ORNL/Y12)
- NCMS

Technology Developers:

- Enterprise Integration Technology
- Lockheed Artificial Intelligence Center
- Stanford University
- University of California at Berkeley

Submitting Consortia Organization: NCMS

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PROJECT AIMS

- Provides Delivery Channels for Dual-Use Facilities
- Integrates Defense and Commercial Sectors
- Improves Production Affordability and Responsiveness
- Establishes Nucleus for National Production Infrastructure
- Supports National Priorities and Initiatives

☺ **Delivers Bottom-Line Benefits in 24 Months**

☺ **Driven by Business Production Requirements**

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THE NEW ENVIRONMENT

Reality - Defense Procurement:

☺ Smaller, Less Predictable, Shorter Cycle.

Response - Defense Contractor:

☺ Permanent and Deep Downsizing.

Result - Defense Industrial Base:

☺ Core Competencies Threatened.

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AS DEFENSE INDUSTRY SEES IT

Environment:

☺ Smaller, Less Predictable, Shorter Cycle Procurement.
☺ Permanent and Deep Downsizing.
☺ Core Competencies Threatened.

Objectives:

☺ Protect Skilled Workers.
☺ Strengthen Core Competencies, Expand Markets.
☺ Maintain Fully Responsive Production Capability.
☺ Improve Cost, Time, Quality, and Risk.

Strategy:

☺ Cease Investments in Marginal Competencies.
☺ Subcontract Outside for Complimentary Competencies.
☺ Develop Markets/Channels for Core Competencies.
☺ Form Virtual Production Enterprise.

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VISION:
VIRTUAL PRODUCTION ENTERPRISE

A National Network of
Dual-Use, Plug-Compatible, Agile Production Facilities;
Exchanging Access to Core-Competencies as a
Seamless Extension of Internal Capability.

☺ **Lean:** Eliminates Wasteful Marginal Capabilities.
☺ **Agile:** Delivers Resources for Unpredicted Needs.
☺ **Competitive:** Strengthens Core Competencies.
☺ **Robust:** Provides Multiple Production Alternatives.

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LOGIC FOR DUAL-USE STRATEGY

1: - New Procurement Strategy Will Emphasize Design and Engineering.
- Thus - Critical Design and Engineering Resources Not Threatened.

2: - Procurement Strategy Will Greatly Reduce Production Needs.
- Defense Production Resources are Threatened.
- Thus - Production Facilities Must Seek Commercial Product Opportunities.

3: - Defense Companies Lack Commercial Sales/Distribution Infrastructure.
- Likelihood of Dual-Use Sales/Distribution Capability is Very Low.
- Thus - Can't Change to Hybrid Full-Service Defense/Commercial Profile.

4: - Therefore - Must Sell Defense Production Capability to Commercial Companies.
- Issues: Competitive Pricing, Delivery Channel, Marketing Channel.

5: Synergistic Opportunity:
- Defense Will Require Highly Agile Production Facilities.
- Such Facilities Will Have A Commercially Competitive Marketable Service.

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AGILE PRODUCTION FACILITY

Thrives on
Continuous and Unpredictable Change.

Rapid Response,
Small-Lot, High Variety Production
Without Compromise In Cost and Quality, and
Significant Improvements in Time and Risk.

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DEFENSE/COMMERCIAL SECTOR SYNERGY

Provides Both Sectors:
- Integrated, Rapid-Response Supply-Base.
- Load Balancing and Surge Capacity.
- Affordable Large/Small-Lot Production.
- Rapid, Affordable Prototype Parts.
- Quality and Cost Options.

Provides Commercial Sector:
- Product-Development Security
- Speciality Core Competencies.

Provides Defense Sector:
- Rapid Reconstitution Capability.
- Defense-Industry Stability.

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A WIN-WIN STRATEGY

☺ Protect Skilled Workers:
- Develop Markets/Channels for Core Competencies.
- Cease Investments in Marginal Competencies.
- Form Virtual Production Enterprise.

☺ Strengthen Core Competencies:
- Offer Core Competencies At-Large, Expand Markets.
- Form Virtual Production Enterprise.

☺ Maintain Fully Responsive Production Capability:
- Subcontract Outside for Complimentary Competencies.
- Form Virtual Production Enterprise.

☺ Improve Cost, Time, Quality, and Risk:
- Cease Investments in Marginal Competencies.
- Subcontract Outside for Complimentary Competencies.
- Form Virtual Production Enterprise.

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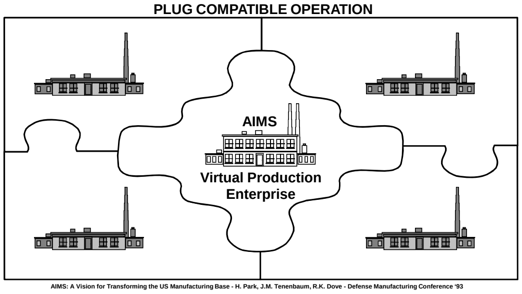
COMPREHENSIVE CORE COMPETENCIES

PLUG COMPATIBLE OPERATION



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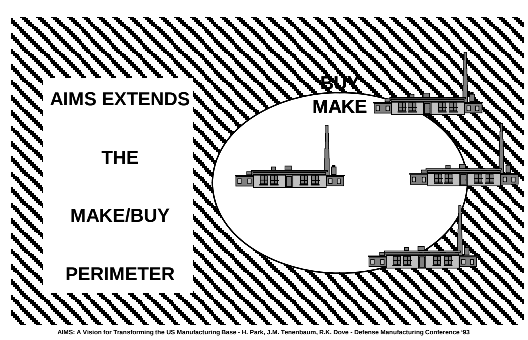

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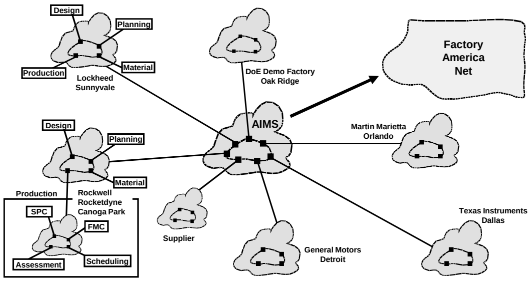
VIRTUAL PRODUCTION ENTERPRISE



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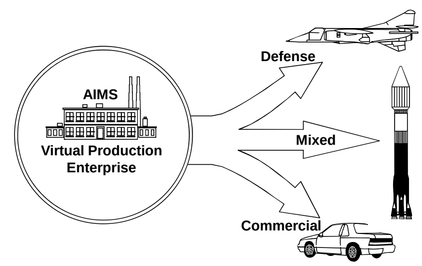
DUAL-USE PRODUCTION INFRASTRUCTURE



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PROJECT PHASES

- ☺ Phase One - 18 Months.
  - ❑ 9 Months: Baseline Benchmarks, Procedures, Metrics.
  - ❑ 18 Months: Functioning Virtual-Production Procedures.
- ☺ Phase Two - 18-24 Months.
  - ❑ Constant Incremental Improvements/Services Throughout.
  - ❑ Productive Scalable Virtual-Production Infrastructure.
  - ❑ Improved Setups, Shop Agility, Procedures, Metrics.
- ☺ Phase Three - 24++ Months.
  - ❑ Constant Incremental Improvements Throughout.
  - ❑ Extension to Any-Part, Any-Where.
  - ❑ Open to Entire Supply Chain Community.
  - ❑ Productive General Purpose Virtual-Production Nucleus.

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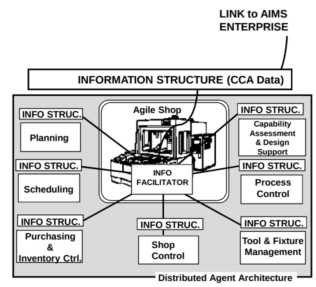
A VIRTUAL PRODUCTION CONSTITUENT

- ❑ Rapid Response To Continuous & Unexpected Change.
- ❑ Flexibility To Handle Variety And Changing Lot Sizes.
- ❑ Economic Incorporation Of New Tools And Methods.
- ❑ Seamless Interoperation With External Systems.
- ❑ Certified Performance.



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DEVELOPMENT & PILOT - FIRST 24 MONTHS

Create Open, Scalable Infrastructure for Agile Manufacturing:

- ❑ Infrastructure: Access Standards for Agile Production Services Over Local Area Networks and Internet.
- ❑ Scalable: From Shop Floor to Company to Other Companies.
- ❑ Open: Anyone Can Offer Services.

Demonstrate Effectiveness in Narrow-Focus 24-Month Pilot Phase:

- ❑ Narrow Focus 24 Month Pilot Phase.
- ❑ 5 Participants Exchange Flexible Machining Services.
- ❑ Business-Case Benchmarks and Agility Metrics Formulated.
- ❑ Core Services Assembled and Developed.
- ❑ Standards for Part Description and Network Interfaces Established.
- ❑ Supplier Compliance Procedures Developed.

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INTERNET COCKPIT SERVICE MENUS

- ❑ Supply Standard CCA (Cost/Capability/Availability) Datasheet
- ❑ Estimate Cost and Deliver for This part
- ❑ Provide a Firm Quote
- ❑ Check This Design and Provide a DFM Critique
- ❑ Generate a Process Plan for This Design
- ❑ Design Setup and Fixturing
- ❑ Submit an Order
- ❑ Check Status of Order
- ❑ Request SPC Part Data
- ❑ Schedule Delivery
- ❑ Engineering Change (Please Acknowledge)
- ❑ Request On-Line Video Conference

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THIRD-PARTY SERVICE EXAMPLES

- Full Service Brokers That Conduct Bids and Post Results.
- Custom and Experimental Application Specialists.

- Automated CAD Format Converting Services.
- Process Planning Services.
- Scheduling Services.
- Material Handling Services.

- Software Toolkits and Libraries for Service Developers.
- Reusable Validated Packaging Modules.

BUSINESS PRACTICES

- Shops Use Automated Costing & Process Planning Services.
- Shops Rely on Brokers to Expedite Bids.
- Shops Might Outsource for Services from Another Shop.

- Direct Access to Customer Document Control System.
- Scalable Services/Bidding on Internal Shop Control.
- Agents Invoke Agents in Preparing Bids and Estimates.
- Finite Dispatch Scheduling Updates CCA Immediately.

ELEMENTS OF AIMS

<u>Business Process - Virtual Production Model</u>
- Common Operating Procedures.
- Re-Engineered Procurement and Contract Acquisition.
- Qualification Metrics and Procedures.
- Expansion and Diffusion Tools.

<u>Information Technology</u>
- Requirements - Strategic and Functional.
- Approach - Build on MADE Reference Architecture.
- Toolkits: Server, Client, Mediator.

<u>Manufacturing Technology</u>
- Changeover/Setup Improvements

AIMS VIRTUAL COMPANY MODEL

<u>Common Operating Procedures</u>
- Standardized Trade Agreements.
- Prequalified Sourcing.
- Predefined Protocols.
- Standard Forms.
- Standard Cost Library.
- Compatible Data Exchange Formats.

<u>Other Major Issues</u>
- Agility Rating Metrics for Production Services.
- Procurement and Contract Acquisition Procedures.
- Network Diffusion and Expansion Tools.

BENCHMARKING AND MODELING

- Model & Benchmark As-Is Outsourcing Process*
- Model & Benchmark As-Is Contract Manufacturing Process**
- Model & Benchmark As-Is Setups and Fixturing
- Establish Baselines for Selected Part Candidates
- Develop Virtual-Production-Enterprise Fixturing Requirements
- Develop Virtual-Production-Enterprise Operating Procedures

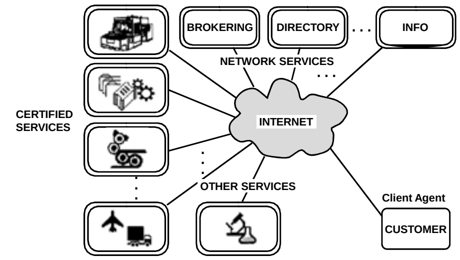
* Involve Purchasing/Contracts Personnel
**Involve Contract Manufacturing Process Personnel

REQUIREMENTS

<u>Strategic Requirements</u>
- Nucleus of National Infrastructure for Agile Manufacturing (FAN).
- Support Agility on the Shop Floor.
- Co-exist with Legacy Systems and Support Graceful Migration.

<u>Functional Requirements</u>
- Openness - Widely Implemented Interface Protocols.
- Scalability - Shop Floor or Around the World.
- Extensibility & Graceful Degradation -
  Add, Remove, Substituted Services at Any Time.
- Compatibility With Legacy Systems Through Encapsulation.

LOOSELY COUPLED CLIENT & SERVER AGENTS



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MADE REFERENCE ARCHITECTURE

APPLICATIONS AND ENVIRONMENTAL LAYER

Collaboration Services	Information Services	Manufacturing Services
Work Environment For Real-Time And Asynchronous Sharing Of Information.	Internet Wide Access to Catalogs, Handbooks, Software Libraries, Design Libraries, Tool Libraries.	Electronic Marketplace For Production Services, and Parts & Prototyping Services.

Process Models: Procurement, Engineering, Manufacturing, Software.

SERVICES LAYER

- ❑ Multi-Media Information Services (Enhanced e-mail, Notemail, WAIS, Navigator)
- ❑ Electronic Commerce (PEM, Directory, Authorization, Billing, Remittance)
- ❑ Federation services (Agents, Mediators)
- ❑ Collaboration services (Xshare)
- ❑ Software Development (Toolkits, Libraries, GUI's)
- ❑ Distributed Computing (Wide-area CORBA, Service mail, IS)
- ❑ Data Exchange Standards (PDES/STEP, IGES, MIME, CFP)

NETWORK/PLATFORM LAYER - Protocols: FTP, HTP, Z39.50, NNTP, KQML.

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SOFTWARE DEVELOPMENT TOOLKITS

Server Toolkits

- ❑ ServiceMail: Internet Mail-Enabled Unix Applications.
- ❑ Internet Services Toolkit (IST): Adds IP, HTTP, NNTP ServiceMail Protocols.
- ❑ Public Disc: Multimedia for ServiceMail.
- ❑ Distributed Information Service (DIS): Enables Network Sharing of Models.

Client Toolkits

- ❑ Information Navigator - Network PC/Mac/Unix GUI .
- ❑ NoteMail - Create, View, Share Multimedia Engineering Documents.
- ❑ X-Share - Real-Time Multimedia Conference & Application Sharing.

Mediator Toolkits (From SHADE Project)

- ❑ Directory Services.
- ❑ Mail Forwarding Agents.
- ❑ Brokers: Post RFQs, Accept Bids, Make Awards.
- ❑ CAD Format Translators.
- ❑ Aggregators: Combine Multiple Orders.
- ❑ Facilitators: Route Part Info Requests, Cause Translation.
- ❑ User Agents: Automate Routine Workflow Tasks

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MANUFACTURING TECHNOLOGY

Agile Machining Services Require Improvement in Five Areas:

- ❑ Fixture Configuration.
- ❑ Part Setup.
- ❑ Part and Process Verification.
- ❑ Cutting Tool Management.
- ❑ Simplified Shop Documentation.

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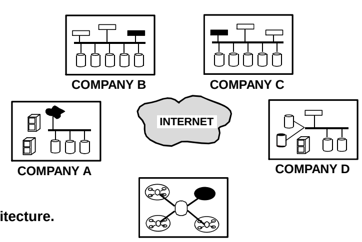
INITIAL STATE



- ❑ Diverse Internal Architecture.
- ❑ Legacy Systems.
- ❑ Local CCA Nodes.

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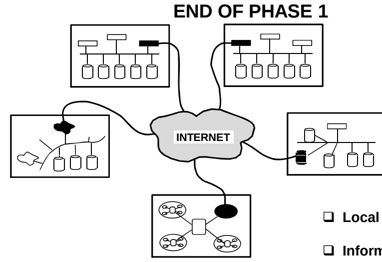
END OF PHASE 1



- ❑ Local CCA Servers
- ❑ Information Navigator
- ❑ Validation Exercise One

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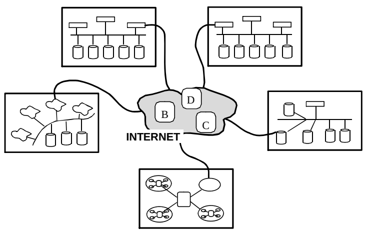
END OF PHASE 2

Interactive Services

- Directory.
- Brokering.
- Information.
- Coordination.
- Translation.



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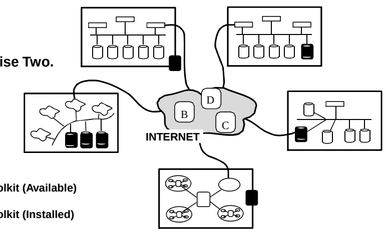
END OF PHASE 3

- Automated Services & Transactions.
- Agent Toolkits.
- Validation Exercise Two.



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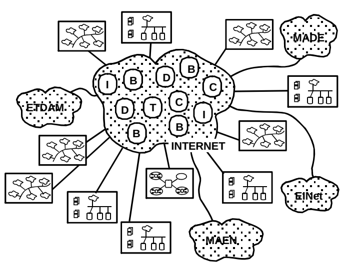
EXPANDED AIMS NETWORK



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CORE ISSUE BENEFITS

For The Defense Sector:

- Defense-Industry Stability.
- Delivery Channels for Dual-Use Facilities.
- Rapid Reconstitution Capability.
- Integrated, Rapid-Response Supply-Base.
- Load Balancing and Surge Capacity.
- Affordable, Rapid Prototype Parts.
- Affordable Large/Small-Lot Production.
- Higher Quality, Lower Cost, Faster Response, Lower Risk Production.

For The Commercial Sector:

- Secure New-Product Prototyping.
- Speciality Defense Core-Competencies.
- Access to Defense Markets.
- Integrated, Rapid-Response Supply-Chain.
- Load Balancing and Surge Capacity.
- Affordable, Rapid Prototype Parts.
- Affordable Large/Small-Lot Production.
- Higher Quality, Lower Cost, Faster Response, Lower Risk Production.

For The Small Supplier:

- Integrated Supply Chain.
- Strategic Relationship with Customers.
- New Markets and Delivery Channels.
- Migration Plan and Diffusion Program.

For The Nation:

- Integrated Defense/Commercial Sectors.
- Production Infrastructure Nucleus.
- New Jobs and New Job Markets.
- National Priority and Initiative Support.

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