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EVALUATION AND RECOMMENDATIONS FOR WORK GROUP INTEGRATION WITHIN THE MATERIALS AND PROCESSES LAB

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The goal of this study was to evaluate and make recommendations for improving the level of integration of several work groups within the Materials and Processes Lab at the Marshall Space Flight Center. This evaluation has uncovered a variety of projects that could improve the efficiency and operation of the work groups as well as the overall integration of the system. In addition, this study provides the foundation for specification of a computer integrated manufacturing test bed environment in the Materials and Processes Lab.

A total of six branches where included in this investigation: EH13 - Non-destructive Evaluation; EH42 - Metals Processes; EH43 - Chemical and Non-Metals Processes; EH44 - Tooling Applications; EH52 - Planning and Control; and EH53 - Fixture Design. The latter two branches fall under the auspices of EH51 - The Fabrication Division. These six branches and their associated systems reside in all or part of buildings 4702, 4705, 4707, 4708, and 4711. The primary mode of investigation was to conduct interviews with key NASA and contractor personnel familiar with the projects and systems within each of the six branches. A total of 45 NASA and contractor personnel were interviewed over the course of six weeks. The purpose of these interviews was to gain an understanding of current projects, assess the current level of automation and integration, and to identify projects that would improve the overall system.

Three aspects of the system were considered in this evaluation: the physical system, the information/communication system, and the managerial/control system. Evaluation of the physical system in an integration study typically considers the level of process automation, the relationship between the various processes (i.e., how material flows through the system), as well as the material handling system. Because the primary focus of the M&P lab is on process optimization the movement of material/items from process to process appears to be minimal. Most items remain within the confines of a particular work area with the primary modes of material handling being forklifts, and overhead cranes (buildings 4705 and 4707). This investigation, therefore, focused on the processes involved, the equipment utilized and how it fits within the overall system.

Evaluation of the information system considered the underlying communications system, the computer systems being utilized, how data is passed from one function to another, the number and types of local area networks in place, what devices are hooked to the LAN, and the information needs of the various work groups. Because of the relatively high level of process automation this became the primary focus of this study. The majority of recommendations made within this document are concerned with improvements to the information/communication system.

Finally, evaluation of the managerial/control aspects of the system included consideration of how well various functions are communicating, which functions interact frequently and how well cross functional projects are being coordinated between functions. Integration of the managerial/control system requires that an organization breakdown barriers between functions. A few recommendations will be made regarding this aspect of the system but time did not permit large scale investigation of the managerial/control structure of the M&P lab.

Assessment of EH13 - Non-Destructive Evaluation: The NDE branch's systems and personnel are housed in building 4702 with the exception of the Computed Tomography Lab in 4707 and the Radiography Lab in 4711. The majority of systems and computers are stand-alone. While there has been some discussion regarding installation of an Ethernet backbone in 4702 none of the engineer's personal computers (PC's) are, at this time, linked to the NASA Ethernet or to the IAN. There is, in fact, only one connection to the Ethernet LAN the Branch Chief's secretary's terminal. Review of the NDE test equipment indicates that a mix of computer controlled and manual systems are currently being utilized. Again, the computer-controlled systems are not networked making them inaccessible from remote sites. As for test records, some areas are still utilizing paper based systems (e.g., the Radiography Lab).

Recommendations to EH13: This branch's primary need is a networking arrangement that allows each of the engineers within the branch to communicate electronically with each other and with personnel outside EH13. Two possible options that should be considered are: 1) installation of a personal computer (PC) based network within 4702 with a link to NASA's Ethernet, and 2) installation of Ethernet cards in all of the computer systems in 4702 allowing them to be directly connected to the

network. The advantage of the PC network is that it would allow the branch to utilize network versions of software and have a common set of software tools (i.e., word processor, spreadsheet, etc.). Either option would be an improvement over the current situation and should increase data sharing and provide a more efficient means of communication with other groups. One concern that must be addressed, regardless of the networking option chosen, is to how to provide access to NDE data while ensuring that good data is released. Also, the network should provide NDE personnel with access to MAPTIS. In addition, investigation should be done to determine how to link the TABS system to the NDE network so that branch personnel can access the information from the personal computer at their desk.

In addition to the installation of a network the NDE branch also needs to utilize database technology for maintaining test records. In particular, a database system should be developed to track test results in the Radiography Lab. Any other areas currently using paper based record keeping systems should also seriously consider converting to a computerized database system. The current paper based system(s) hinder retrieval and analysis of the data. Development of a computer based system should provide a more efficient and effective means for retrieving and analyzing the data.

Assessment of EH42 - Metals Processes: The systems utilized by the Metals Processes Branch are housed in portions of buildings 4705, 4707, and 4711. Overall, these systems exhibit a high level of process automation. A number of robotic and computer controlled welding systems are in place, however, the majority of these are stand-alone. Only two systems are currently linked to NASA's Ethernet, the old Cincinnati Milacron robot welding system in 4705 and the Vacuum Plasma Spray Cell in 4707. With the acquisition of some new systems there are 3 or 4 different controllers being utilized, limiting the transportability of weld schedule data. The oldest controller, the taper weld controller, was developed in the 1970's and is technologically dated. The newest system, the Motoman K-10 robot, utilizes a VME based, Ethernet compatible, controller. Plans are being developed to eventually replace the existing controllers with VME based, Ethernet compatible, controllers similar to the one on the Motoman K-10 robot.

In addition to the welding systems, the Vacuum Plasma Spray Facility, in 4707, exhibits a high level of process automation. The process is entirely computer controlled. It is also directly linked to the NASA's Ethernet backbone, allowing programs to be developed off-line and downloaded to the controller directly. This system is also setup to log data during operation.

This study also revealed that historical documentation of the R&D work going on in this branch is predominantly paper based. There is, at present, no common database of weld schedule information that NASA and contractor personnel can access to see the types of setups run in the past. Information sharing is done on an informal basis. A paper based system is currently being developed to keep track of weld schedule information and the resultant test results. While such a system is a good start an electronic database would make the retrieval and sorting tasks easier as the database becomes larger. It should be noted that some initial work was done with Intergraph to develop such a system but it was never fully implemented and is not currently being utilized.

Recommendations to EH42: This branches has two primary needs. First, they should continue to upgrade the welding controllers to VME based Ethernet compatible systems. Ultimately these systems can be linked to the Ethernet backbone, providing engineers with remote access to programs and information on the controllers. It should be noted that these new controllers should be GOSIP compliant if possible. GOSIP (Government Open System Interconnect Protocol) is a coming requirement for all government systems. This new standard is directed at the installation of open systems and promotes interoperability, which should be beneficial to the M&P lab because of the wide variety of computers and systems being used. After upgrading the controllers the most pressing need within this branch is the development of electronic databases to track and capture the R&D work under way. As has been mentioned, there is currently no central repository for weld schedule information it is presently scattered among several engineers log books. Three areas that could benefit by the development of a database system are Welding (i.e., weld schedule information and test results), the Vacuum Plasma Spray Cell (i.e., system settings and results), and the Materials test lab in 4711.

Assessment of EH43 - Chemical & Non-Metals Processes & EH44 - Tooling Applications: The areas supervised by these branches contain a wide variety of computers, controllers, and systems. In general there is a high level of process automation with a few manual processes. Most of the systems are, however, stand-alone with no link to NASA's Ethernet LAN. The most common means of passing programs to the controller is a serial connection between the controller and a remote PC or workstation.

As for the communication system, it was discovered that there are two separate, unconnected, Ethernet segments within Buildings 4711 and 4705, a NASA segment and an Intergraph segment. Data can be passed between the two systems by setting the files on a VAX that is accessible by both systems and pulling the file to the desired system. While passing data is possible it is cumbersome for most operators and may, in the long run, limit data sharing. In addition to the Ethernet LAN's a Novell network has recently been established to link PC's within building 4711. At present there are 50 users on the system and plans to expand to ~250 users in the future. This system should ultimately provide an efficient means of communication and data sharing within this facility.

Recommendations to EH43 and EH44: These branches should consider upgrading the controllers that see the greatest use of off-line programming. Again, any upgrades should be Ethernet compatible and GOSIP compliant. The greatest difficulty with making this recommendation is the fact that current activity levels make this cost prohibitive. Thus, it is suggested that three strategies be considered: 1) Establish a direct serial connection between the machine controller and a remote PC/workstation. This is essential what has been done to date. 2) Use a PC, hooked to the Ethernet LAN, with a serial connection to one or more controllers, as a remote storage device accessible over the network. This strategy will provide wider access to programs and data via the network. 3) Upgrade to Ethernet compatible and GOSIP compliant controllers. This is the most comprehensive strategy giving remote users full access to the controller. It is, however, the most expensive solution and, given the current level of activity in many areas, the most difficult to justify.

With regard to the communication system, eventually the NASA and Intergraph Ethernet segments should be integrated. The present configuration maintains redundant systems unnecessarily and limits data sharing. Technologically, there are no reasons that they cannot be integrated or at least linked together to provide a more efficient means of passing data. As for the Novell network in 4711, there is a need to establish an effective means of linking engineers on the PC LAN to the larger Ethernet LAN. This investigation indicated that, at present, not all engineers have access to the IAN. Also, there is a need to establish a set of procedures for passing documents/reports from commonly used PC based word processors to the CEO systems used by other divisions of NASA. While these procedures may already be in place there is a need to make sure that all users are aware of them. Passing data between the two systems should eliminate the need to recreate reports in CEO for wider distribution. Finally, as with the Metals Processes branch EH43 and EH44 could benefit from the use of database technology to maintain records of machine settings and experimental test results within in the various R&D areas (i.e., composites, MSA, etc.).

Assessment of EH52 - Planning and Control: The Planning and Control Branch of the M&P lab and is concerned with the manufacture of a wide variety of items, including everything from experimental fixtures and devices to flight hardware. They supervise the manufacturing facilities housed in 4705. The current manufacturing system contains a mix of computer controlled and manual systems. Some off-line programming is being done using Intergraph's I/NC package, however, some programs are still being developed manually. At present four machines are linked to this CAD/CAM system via a serial connection. Three or four recently installed machines could also be connected. The primary purpose of the direct connection is pass programs to the controller.

The production planning task utilizes the Integrated Manufacturing Planning and Control System (IMPACS) a scheduling system developed with the assistance of Boeing Computer Services. This system appears to be good for a job shop type environment such as EH52. Unfortunately, not all of VerVal's planners have access to the system. The system has evolved to its current configuration over the last seven years. Several initiatives are presently underway to enhance the IMPACS system and further integrate it with other NASA systems. Another system, the Manufacturing Inventory

Management System (MIMS) is used to maintain and track the material and parts inventory in 4705.

This branch also has a producibility group which checks drawings for correctness and provides feedback to designers on manufacturing considerations. This group appears to be a good start toward concurrent engineering.

Recommendations to EH52: The most pressing need of this group is improved communication and cooperation with other groups. Serious consideration should be given to forming a TQM/CI team to evaluate the design process and identify ways to improve communication and cooperation with the fabrication personnel. While the CAD/CAM system appears to be working adequately programming efficiency could be improved through increased communication between the programmers and the designers. At present a large proportion of the drawings are sent on paper. Thus, the programmers must recreate the drawings on the Intergraph system, often a time consuming process. Unfortunately, even when CAD files are sent they may not be Intergraph compatible or, when they are, they may not be in a format usable by the programmers. In these instances, the programmers must recreate the drawings on Intergraph or manually develop the NC program. Three things are needed to alleviate the problem of redundant drawing entry. First, designers need to be educated on the needs of the NC programmers. In particular, it would be useful to establish some basic guidelines for CAD drawings to ensure that the NC programmers will not have to modify them. Second, Intergraph compatible files should be sent when possible. If this is not possible then translators should be purchased for the most common file formats. Reviewing the CAD/CAM system also highlighted the need for increased communication between the fabrication personnel and the designers. While the producibiity group is a good start toward concurrent engineering there is still a need to get fabrication involved as early in the design process as possible. In addition, to giving designers feedback on the producibiity of their designs early involvement of fabrication makes designers aware of current shop capacity and expected lead times. It also allows the planner to begin early consideration of the make/buy decision.

With regard to the planning and control system the branch should continue their efforts to improve and expand the capabilities of the scheduling and inventory systems. Specifically, the IMPACS scheduling system and the Procurement Management Information System (PROMIS) should be linked. At present planners can access some information from PROMIS but there is a need to expand the screens available to allow the planner to monitor the status of outstanding purchase orders. Also, the Inventory system (MIMS) and the Automated Procurement Request System (APRS) should be modified to allow users to copy inventory information directly into APRS thereby reducing data entry time when creating long lists of purchased items. Finally, long term, the planning and control branch needs a real time scheduling system that would allow schedulers to assess the scheduling impact of new orders and the changing priorities of existing orders.

Assessment of EH52 - Fixture Design: This is the design branch of the M&P Labs Fabrication Division. The personnel and systems in this branch are housed in 4708. The development of designs is predominantly CAD based, utilizing a VAX based version of Intergraph's Engineering Modeling System [EMS]. This CAD system is linked to Intergraph's Ethernet and is used for drawing development and design analysis. Two or three Intergraph workstations are being used also, primarily for analysis. Also, while of the engineers have PC's in their offices they are not, at present, on a local area network or linked to either of the Ethernet systems or the IAN.

Recommendations to EH53: The present CAD system appears to fulfill the present needs of this group. In the future consideration should be given to moving toward networked workstations, given the current trend in the CAD/CAM industry toward distributed systems. A more important need in this area is an emphasis on increased communication between EH52 and EH53 early and often during design development. It appeared from talking to personnel from both branches that increased communication would benefit both groups. The designers need to be aware of the documentation needs of the fabrication people, particularly for items that will be run on NC equipment so as to reduce the need to recreate drawings just for program development. Fabrication needs to be aware of the jobs coming in so that the make/buy decision can be made early so the final customer can be given a good estimate of the expected delivery date. In addition, early involvement of the fabrication personnel will help to reduce the instances of designs that are difficult or impossible to produce. One

hindrance to communication is the fact that the EH52 and EH53 are located in separate buildings. Serious consideration should be given to locating the branches in the same building and, if possible, having the designers and planners share office space. Co-locating personnel from different functions would encourage informal communication and is one way to begin to breakdown functional barriers. Both branches need to gain an appreciation for the needs and concerns of the other.

Recommendations regarding Managerial/Control System: In addition, to the many branch specific recommendations a few managerial/control issues should also be addressed. While some of these recommendations echo those made earlier there is a need to reiterate and address them in the larger organization. The M&P lab and NASA in general, are in the midst of a large scale cultural change. From this investigation it was evident that the greatest need within the M&P lab is improved communication between divisions, between branches, and even in a few instances within branches. The personnel within the branches need to gain an appreciation for the needs and concerns of the other branches that they interact with, thereby breaking down functional barriers. The current emphasis on TQM and Continuous Improvement should continue to be strongly supported and encouraged by M&P lab administrators. TQM/CI is an important means for improving communication and helping personnel to gain an understanding of the processes that they are involved with and support.

More specifically, an evaluation of the R&D process needs to be undertaken. This evaluation should focus on ways to improve coordination among all groups involved in experimentation within the M&P lab. The current process seems to lack firm procedures for setting up and conducting experiments that involve several groups within the lab. Consideration should also be given to increasing the use of experimental design/Taguchi methods for setting up and conducting experiments. These techniques promote experimental efficiency and maximize the learning process. There is also a strong need for utilizing database technology to maintain historical records of research setups and results. In several cases, there appears to be no formal mechanism for capturing this information and making it available to NASA and contractor personnel. Ultimately, analysis and interpretation of these records could provide the foundation for establishment of knowledge bases to support future experimentation and investigation. Finally, in the area of systems management, there is a need to promote communication between groups involved in the specification and purchase of new equipment. They must communicate their needs to current system administrators to ensure that the equipment they are specifying is compatible and can be easily integrated into the existing system. As has been mentioned previously, there is a need to purchase systems that are GOSIP compliant which, if the promises hold true, should improve the integration of the overall system.

The facilities and systems that comprise the Materials and Processes Lab are quite impressive. Overall, the greatest need in the M&P Lab is better communication and cooperation between branches and functions. While the TQM/CI initiatives promote and support this, individuals are the ones that make it happen. NASA and contractor personnel at all levels, must buy into the idea that cooperation will take everyone farther than competition ever could. Because many of the projects and initiatives currently underway in this lab involve several different groups there is a strong need for communication to ensure that the goals of the program(s) are achieved in an effective and efficient manner. A second need that must be addressed is for individual project leaders to take a systems viewpoint when specifying, purchasing, and installing new equipment and systems. New systems must be specified with an understanding of how they fit into and support the overall system. The future must see a renewed emphasis on the integration of existing systems into the larger communications system. The benefits associated with these two fundamental suggestions, as well as the more specific recommendations mentioned previously, are a breaking down of functional barriers, increased efficiency, and a better foundation for knowledge development and retention.