Summary

This paper describes a concept of modular aircraft support equipment that combines several maintenance and servicing utilities in single carts. This design innovation, called Multifunction Aircraft Support System (MASS), will reduce the mobility footprint for combat deployment and help to reduce the proliferation and cost of aerospace ground equipment in peacetime.

Introduction

Most of the Air Force's inventory of Aerospace Ground Equipment (AGE) is intended to perform a single function only. Separate wheeled carts provide electrical power, engine start air, cooling air, hydraulic and pneumatic pressure, lighting, and other utilities needed for aircraft servicing and repair. Although some types of powered AGE are used on different aircraft types, many aircraft also have unique servicing requirements that demand "peculiar" AGE. Over decades, the practice of buying single-function and single-aircraft AGE has led to undesirable proliferation.

Support equipment is usually bought off-the-shelf. They have had little incentive to consider reliability, maintainability, and related logistics support factors in the design of this equipment. Air Force attention to supportability has extended primarily to major weapon systems, not to AGE. The equipment tends to be bulky, unreliable, and often difficult to repair.

There is a separate enlisted specialty just to manage and repair the equipment at base level. Above base level there is a large AGE repair and procurement apparatus. This complex structure is driven in part by the diversity of support equipment requirements and the lack of standardization in design.

Under current and foreseeable regulations from environmental protection agencies, the Air Force must reduce air pollution from its installations. Diesel and gasoline burning engines used in AGE are significant sources of air pollution from Air Force bases. At present, the air pollution from ground support equipment at March Air Force Base in Southern California is receiving special attention. The Air Force is evaluating several options for reducing nitrous oxide and hydrocarbon emissions from operations at that site.

Finally, and perhaps most significant, consider these problems from the standpoint of deployment. Depending on how support equipment is accounted for along with other rolling stock, a mobilized unit may count up to half of its total airlifted weight in flight line support equipment alone.

- In a mobility study by Air Staff in 1989, a typical F-16 deployment package of 24 fighters needed five C-141 equivalent loads just for transportation of its support equipment. This equipment includes electric generators, hydraulic mules, air conditioners, nitrogen carts, light carts, and so on.

- In a more recent study by Northrop of a composite wing deployment, it was estimated that 25 percent of the deployed weight and 20 percent of the deployed volume was flight line support equipment.

More than ever, air mobility must have long legs and a short tail. Global reach for air power requires a focused effort to reduce the logistics tail. AFMC Regulation 500-23 titled Reliability, Maintainability, and Deployability (RM&D) recognizes this need.
It calls for new acquisition and technology investments to be evaluated in terms of their impacts on deployment. Innovations in support equipment design that reduce the logistics tail for deployment will respond directly to this new need.

Many solutions to the support equipment problem have been proposed. For example, wider use of auxiliary power units and/or jet fuel starters would eliminate some types of AGE. Electrical power from onboard generators can support maintenance and servicing needs under many conditions. Greater standardization and improved R & M would also reduce proliferation by promoting interchangeability of components and reducing requirements for spares.

**Multifunction Support Equipment**

Another solution is to develop multifunction support equipment. By combining electrical power, hydraulic, air, and other utilities in one wheeled unit, the number of powered AGE carts needed for aircraft maintenance would decline. The logistics footprint for deployment would be substantially reduced. The Northrop study estimated that multifunction support equipment would reduce the logistics footprint for a composite wing deployment by the equivalent of three C-141 sorties. Scarce airlift for contingency support could then be allocated to other needs.

Multifunction equipment design is not by itself complete solution to AGE problems, but it would bring these added advantages if successfully and widely implemented:

- Flight lines at main operating bases would become less crowded. The potential for mishaps would decline. This could be a special advantage in combat conditions that demand quick turnaround maintenance. MASS machines would promote efficient and safe use of support equipment for rapid combat maintenance turns.

- Small unit deployments would become more feasible since fewer items of support equipment would be needed for aircraft servicing at dispersal sites. Tactical relocation of aircraft to bare bases requires limited and flexible ground support assets. Multifunction AGE serves this combat objective.

- Manpower and training requirements would decline if multifunction AGE technology replaced existing machines. Technicians would learn how to operate and repair one unit, not a dozen. Job enlargement through cross-training would drive manning requirements down without eroding work force productivity. The MASS concept is analogous in some respects to the Rivet Workforce idea. The former combines equipment functions into one versatile machine; the latter combines work tasks across specialties to create generalist aircraft maintenance technicians. Logistics resources, both manpower and equipment, should decline as these innovations take hold.

- If attention is given to modularity in design and packaging, to reliability, and to ease of maintenance during engineering development, a MASS approach would simplify logistics support requirements at all levels compared to current requirements for powered support equipment. There would be fewer machines to manage and repair, and modular design ideas would permit flexible use of subsystem parts, including parts drawn from currently fielded AGE carts. The objectives of "Lean Logistics" would be furthered by this approach to support equipment configuration.

- The MASS concept would also lead to lower overall support equipment acquisition and ownership costs. The versatile machines we envision would cost less than the single-function machines they would eventually replace. With reduced budgets and increased attention to affordability in system design and technology investments, multifunction support equipment appears to be a highly leveraging concept for logistics support.

- Dual uses for MASS in commercial aviation and in inter-service applications are likely. The Army and Air Force already use multi-function units for helicopter maintenance. The RAF (Great Britain) and
other air forces are also potential users of MASS technology.

Requirements for MASS Technology:

The Air Mobility Master Plan (Aug 94) requests MASS design studies in FY 95.

Air Force AGE Master Plan (Mar 94) calls for research and technology development on MASS as the highest priority need.

MASS Technology Development

Armstrong Laboratory has organized an Integrated Product Team (IPT) to coordinate design studies and technology developments leading to a demonstration of MASS capabilities by early 1998. Key players in this are Wright Laboratory, the using commands, Aeronautical Systems Center, and the Air Force Aerospace Ground Support Equipment Working Group (AGSEWG). A four-year cycle of research and engineering design will culminate in the creation of a MASS technology demonstrator for test and evaluation. In 1995 we are performing a series of technology surveys, configuration trade studies, and cost analyses. In 1996 we will develop engineering and fabrication plans for a MASS technology demonstrator that can be field tested beginning in 1997. The transition concept is to develop engineering and manufacturing specifications to the appropriate procuring agency for acquisition and fielding of a production unit by the end of this decade.

The technology we envision is a (far) less-than-major system which will use mainly off-the-shelf components. The MASS technology demonstrator will include many new engineering ideas, but it is best viewed as a system mod, not an entirely new system. The leading technological innovations of the R & D are likely to be found in system configuration, packaging, and supportability concepts in MASS design.

Reliability, maintainability, and deployability will be stressed in our system engineering approach to MASS. Compared to existing equipment, a MASS unit should fail less frequently, be easier to use and repair, and reduce mobility footprint.

MASS Configuration Options

The baseline configuration for a MASS machine will include an engine and generator combined with an air conditioning module. Maintenance engineering analyses of specific aircraft servicing requirements as well as user surveys will guide us in the selection of other functions for MASS. These include nitrogen servicing/generation, hydraulic power, high and low pressure pneumatic air, and lighting. In addition, we will evaluate the feasibility of self propulsion to allow the MASS unit to tow itself, other pieces of AGE, and possibly some types of aircraft around the flightline.

If all such options were successfully incorporated, the MASS machine would replicate the functions of seven major types of powered support equipment. Specifically, the MASS unit has the potential to replace:

- The -60 and -86 Generator Sets
- AM 32C-10 Air Conditioner
- NF-2 Light Cart
- Nitrogen Servicing Trailer
- MC-1A Compressor
- MC-2A Compressor
- 2- and 3- System Hydraulic Test Stands

Methods for reducing air pollution from internal combustion AGE engines will receive special attention. It is conceivable that conversion to MASS machines by itself would reduce the aggregate emissions from flightline operations since fewer engines would be burning fuel. But solutions that reduce emissions from each exhaust pipe will ultimately be needed. A number of options for reducing nitrous oxide and hydrocarbons are being explored. One is to design MASS machines so that they can draw electricity from the base power distribution system through ground receptacles installed on the ramp. A gas or diesel engine would not be used in peacetime on CONUS bases. For combat use, the MASS machines could be
reconfigured with a conventional engine. Another option is to add an exhaust treatment module to powered AGE to remove pollutants. In this approach, existing AGE engines and fuels would not have to be replaced, and breakthroughs in combustion technology would not be required. Pollution control units would not be deployed. The advantages and disadvantages of options like these are being considered in the system engineering trade process for MASS.

To maximize the utility of MASS machines across the Air Force, the units would have to be able to service the widest possible array of aircraft in the inventory. It is not yet known whether a MASS machine in a unitary configuration can meet the full range of power requirements of large aircraft like the C-141 and C-17 and smaller aircraft like the F-16 and F-22. To meet other design criteria, the MASS unit must be small enough to be airlifted on currently assigned cargo planes. MASS design trade-off studies must be informed by data on specific ground maintenance and servicing requirements of specific aircraft.

**BASIC MASS TRADE-OFF**

![Figure 1. MASS Power Needs](image)

**MASS Supportability**

We will use modern logistics analysis tools to illustrate, predict, and compare operational and maintenance requirements of candidate MASS designs. Several tools developed from other research efforts at the Logistics Research Division will contribute to this logistics support emphasis in MASS design.

- **Human Modeling:** Animated 3-D computer graphics allow us to visualize and verify many aspects of logistics supportability from the maintenance technician's perspective before equipment is actually built. The Laboratory's DEPTH human modeling technology will be used to assess maintainability factors such as access, visibility, and task safety for candidate MASS configurations using electronic mock ups.

- **Reliability and Maintainability Allocation and Trade-off:** To forecast MASS component and system reliability, spare parts, and costs. MASS must be designed for high reliability. Since all MASS utilities will rely on a single power plant, the power plant must have a very high reliability rating.

- **Requirements Capture:** We will use a software tool currently under development called RAPID-WS (Requirements Analysis Process in Design of Weapon Systems) to identify, track, and manage MASS requirements and trade-offs throughout the system engineering process. The tool contains a version of Quality Function Deployment, an approved trade-off method, that will relate MASS "whats" to technology "hows" through a multidimensional matrix called the House of Quality.

- **Logistics Resource Simulation:** To define the optimal mix of MASS units and other varieties of support equipment at base level in the context of sortie production needs in deployment scenarios. Logistics resource simulation using a new laboratory technology known as the Integrated Modeling Development Environment (IMDE) will help to: (a) define meaningful reliability thresholds for MASS, (b) estimate how many units might be needed to equip combat squadrons deployed, and (c) how different configuration options and operational concepts for MASS...
might impact sortie generation in simulated combat scenarios.

- **Power Requirements for MASS:** Aircraft power requirements (i.e., electrical, hydraulic, pneumatic) for specific maintenance and servicing needs are being defined with the aid of support equipment databases now being developed by the Logistics Research Division. This data base development effort, known as COLORS (Contingency Operations Logistics Requirements) will, for the first time, identify requirements of specific aircraft for specific types of ground power and map these to maintenance and servicing needs. The principal use of these data will be in establishing valid performance parameters for MASS machines. The power requirements of military aircraft of other nations with whom we might share maintenance resources during conflict will also be included.

- **Other Support Equipment Innovations:** Multifunction support equipment is not the only innovation that will increase efficiency and reduce deployment footprint. These are currently being developed and assessed in a companion research effort known as SEE/IT (Support Equipment Evaluation/Improvement Technologies).

**Technology Issues in MASS Design:**

There are many engineering trade-offs and technology choices to be confronted in MASS design. In addition to those discussed above, these include:

- **Modularity:** The need for swap-out component design extends beyond cost and logistics supportability considerations. To maximize combat value, MASS might be reconfigured for specific deployment scenarios. A "tailored" MASS design concept will require special attention to modular design concepts to achieve this flexibility.

- **Fuel:** It would be desirable from a logistics point of view to fuel the MASS with the same jet fuel used in the airplane engines. A multi-fuel engine seems desirable.

- **Electrical Quality:** Some aircraft require "clean" electricity at specific output levels, while others may tolerate slight variation in power output.

- **Materials:** It may be desirable to make the enclosure and other MASS hardware from advanced plastics. This would reduce weight and corrosion. On the other hand, if the machine is damaged it may be harder to repair. Composites also cost more than sheet metal.

- **Self Propulsion:** The versatility of MASS could be increased if it had a drive train allowing it to move under its own power. But this would also add cost, weight, and mechanical complexity.

- **Towing:** If self propulsion is added, the MASS might also be used to pull itself and other wheeled equipment around the flight line.

- **Condition Monitoring:** Circuitry and displays for condition monitoring will inevitably lay stress on the reliability of built-in test in MASS maintenance concepts.

- **Nitrogen Generation:** Should a MASS carry nitrogen bottles only, or should it be able to generate inert gas? Cost, complexity, and support factors must be considered.

- **Redundancy:** With very careful packaging, it may be possible to obtain redundancy for some MASS functions within the constraints of overall size and weight for the unit. Such redundancy may be needed to meet availability goals.

- **Simultaneous Use:** In some operating environments it might be useful for MASS units to supply power to two different aircraft at the same time. It may be possible to design MASS units for such tandem uses. We are studying power combinations that are most valuable and feasible.