# CHAPTER V

## *A NEW ERA FOR HUNTSVILLE DIVISION*

The history of Huntsville Division in the period 1972 through 1976 represents a sharp contrast with the first five years of it existence. Organized in 1967 with an exclusive dedication to BMD facilities design and construction, the Division then had a mission with high national security implications, large funding, great technical sophistication, and close interaction with the social, political, and economic environment of the times. Thus, the BMD mission remained the Division's single focus for the next five years. After 1971, however, the single orientation of the Division began to give way to a broad variety of new missions as BMD settled back into the research and development status it had enjoyed before the deployment decision of 1967. With the assumption of new and various tasks for a diversity of military and civilian customers, the second era in the history of Huntsville Division began.

In November 1971, even before the impact of a SALT treaty was felt, the Division had been handed a large-scale procurement mission for the newly created United States Postal Service; in 1972 the Postal Service was joined by another civilian customer when the Division was asked to design and construct several test facilities needed for NASA's Space Shuttle program. In late 1973 a third customer, the U.S. Army Material Command (AMC), was added to a growing list of patrons when the Division assumed responsibility for facility design and construction of the Army's massive nationwide Munitions Production Base Support Construction Program (MPBSCP). Finally, in 1975 and 1976, Huntsville Division became involved in the Energy Research and Development Agency (ERDA) coal conversion program, with planning for a Jordanian Armor Rebuild and Conversion Facility, and with procurement for the Corps of Engineers construction activities in the Kingdom of Saudi Arabia. By the end of 1976, Huntsville Division had been, or then was, engaged in a multiplicity of tasks, none of which resembled the Division's original BMD birthright.

The many-sided face of the Division's new era, however, was somewhat deceiving, because in each of the new missions assumed, one or more of three factors common to the Division's BMD heritage could be identified. Several of the new assignments--the Postal mission, the MPBSCP, and the Saudi Arabian mission, for example--revolved around the need to bring a degree of central coordination and management to a national (or even international) program that was quite suited to the capabilities of the Huntsville Division. Second, many of the Division's new tasks were concerned with large-scale and long-range procurement of technical, mechanical, or industrial items similar to the procurement carried out under SAFEGUARD's GFP program. Third, a need for the development and application of highly sophisticated engineering criteria in technical, mechanical, or industrial construction could be especially identified in the ERDA and MPBSCP missions and to a lesser degree in the NASA Space Shuttle and Jordanian Armor Rebuild Facility missions. Taken separately or in combination, exceptional proficiency in these unusual requirements mandated that the responsibilities of the Huntsville Division remained, as in its first five years, unique within the Corps of Engineers.

The phasing in, execution, and phasing out of several complicated programs over several years makes a purely chronological account of them more confusing than clarifying. It should be noted, too, that the Division's internal organization was often reshaped along functional lines in correspondence with the new missions. Certain divisions, branches, or sections sometimes bore primary responsibility for one or two missions only. The Postal mission, for example, was largely, though not exclusively, the work of specialized postal branches within the Procurement and Supply Division, with the Division having no engineering design responsbility. Similarly, other specialized offices for NASA engineering and construction and for Saudi Arabian support appeared on Divisional organizational charts as the need arose. For reasons of clarity, therefore, a topical and functional rather than a year-by-year treatment of Division activities after 1971 has been followed. This Chapter describes the Postal and NASA missions; the MPBSCP, ERDA, Jordanian, and Saudi Arabian missions are considered in subsequent chapters.

### The Bulk Mail Centers Procurement for the U.S. Postal Service

The origins of Huntsville Division's bulk mail center procurement for the U.S. Postal Service can be found in the formation of the USPS as a semi-autonomous agency and a concomitant effort to modernize and mechanize its mail handling functions. By the later 1960's, the facilities and operations of the United States Post Office Department were generally

recognized as outdated and inefficient. In an age of automation, computers, and assembly line mechanization, the Post Office Department continued to do business much as it had twenty-five or even fifty years before. Most of the nation's mail, whether letter or package, was still hand sorted and hand delivered. Moreover, most of the Department's operations were notably unspecialized, all kinds of mail handling being carried on in multi-task facilities located in downtown urban areas. These congested conditions made access for trailer truck mail carriers difficult, while the buildings themselves were of monumental "Federal Style" architecture, expensive to build and almost equally costly to convert or maintain.

By the end of the 1960's, the deficiencies inherent in the Post Office Department's operations were being exposed and aggravated by a rapidly increasing volume of mail passing through the system each year. A thorough reform of the Department seemed in order, and the impetus towards that reform was provided in 1969 when newly-elected President Richard M. Nixon appointed Winton M. Blount as Postmaster General. Blount's reform ideas were inspired by his background as a successful businessman in private life; as Postmaster General he attempted to apply the principles and methods that had been successful in American industry to the modernization of the Post Office Department's infrastructure. Soon after becoming Postmaster General, Blount inaugurated a far-reaching plan to remove the Department from the arena of national politics by having it reorganized as a public corporation called the United States Postal Service (USPS). Thus rendered semiautonomous, the Service would be able to carry out sweeping reforms and modernization and perhaps even be able to free its budget from annual Congressional subsidies.

One of the linchpins of Blount's reforms was subdivision of the USPS into fifteen Postal Regions with regional headquarters in major cities. Another was a virtual revolution in the handling and sorting of mail based on the differentiation of mail types and a high degree of mechanized processing. Beginning about 1970, mail flow in the United States would take two broad channels according to priority and weight. First class letters and other high-priority articles termed "preferential mail" would be routed through automated machinery in Preferential Mail Centers (PMC's) and local post offices. According to the Blount plan, several hundred PMC's and smaller postal facilities would be newly built, renovated, or expanded to accommodate machine handling of preferential mail.

Paralleling the preferential mail system and integrated with it at Post Office inlets and outlets was a Bulk Mail System which would comprise a national network of twenty-one physical plants--the Bulk Mail Centers, or BMC's--located on the periphery of urban areas and near modern transport facilities, interstate highways, and airports. The completed system would include two large BMC's outside New York and Chicago; five medium BMC's near Los Angeles, California; Pittsburgh, Pennsylvania; Philadephia, Pennsylvania; Springfield, Massachusetts; and Dallas, Texas; and fourteen other Small BMC's. Designed along functional lines without the requirements to act as public post offices, the Centers were essentially light industrial-type utility buildings sheltering computerized mechanisms and other high speed mail handling equipment to sort packages, parcels, and other bulk items. The multistory facilities ranged in size from seven to twenty-five acres under roof. The total cost for the Bulk Mail System program was at the time projected at more than $950 million with an estimated annual cost savings of approximately $300 million, or over $800,000 per day (1971 dollars). The System was to be operational by FY 1975 in order to maximize the economies anticipated from its implementation.[1]

The construction envisioned for the Preferential and Bulk Mail Systems was an ambitious undertaking, and in carrying it out the Postal Service had several options. The Service itself should have carried out the construction, even though it lacked the capacity and would have had to resort to a rapid, massive, and rather wasteful buildup of specialized managerial and engineering talent that would be rendered superfluous after the program was finished. Other Governmental agencies such as the G.S.A. likewise seemed to lack the capability, personnel, or expertise to tackle a construction task of this magnitude.[2] By comparison with other options, utilization of the U.S. Army Corps of Engineers offered several advantages. The Corps of Engineers was a substantial force-in-being with an enormous repository of experience with complex, special purpose construction projects. Since the Corps was already a well-established, functioning organization, it could immediately assume responsibility without a large-scale recruitment and mobilization campaign. Its decentralized regional network of divisions and districts enabled the Corps to easily adapt to the extensive work required. Finally, the additional burden of the Postal Service support mission could be assumed efficiently, without

exaggerated increases in personnel or adverse impact on its other activites.[3] A legal authorization for such military assistance to a civilian agency was specifically asserted in Public Law 89-298, Section 219 (79 Stat 1089, Title II, "Flood Control Act of 1965"), which states:

> The Chief of Engineers, under the supervision of the Secretary of the Army, is authorized to accept orders from other Federal departments and agencies for work or services and to perform all or any part of such work or services by contract.[4]

The Post Office Department extended initial overtures for postal construction to the Chief of Engineers in March 1969, only a few months after Postmaster General Blount took his seat in the Nixon cabinet and before the USPS was born. Negotiations and discussions between the Chief of Engineers and the Postmaster General continued for the next eighteen months while the transmutation of the Post Office Department into the U.S. Postal Service was carried out. The Postal Reorganization Act was passed by Congress on 12 August 1970, and on 26 September 1970 the Postmaster General requested the Secretary of the Army to provide assistance in real estate, design, and construction needed for the Postal Construction Program. While negotiations progressed towards the formulation of Memoranda of Agreement covering all postal construction, the Corps proceeded with assistance to the Postal Service on a project-by-project basis. Ultimately, the Corps participated in twelve such individual postal construction projects during 1970-1971, including post offices at Fort DeRussy, Hawaii, and Kearney, New Jersey, as well as a preferential mail facility at Memphis, Tennessee. These dozen projects can properly be considered as the genesis of the Corps of Engineers' participation in the Postal Service support mission that came in 1971.[5]

On 11 March 1971, the relationship between the Corps of Engineers and the U.S. Postal Service was formalized in two agreements. The first covered policies and general principles to prevail between the two agencies. It designated the Corps as Department of the Army spokesman and representative for all postal facilities and acquisition matters; it committed the Chief of Engineers to further development of working agreements; and it established the levels of responsibility. Under the provisions of this Memorandum, the Corps was granted substantial authority in the areas of real estate, design, construction, and contractual services. All funding was to come from Postal Service sources.[6]

A second Memorandum of Agreement of 11 March 1971 erected a formal Corps of Engineers organization to centrally manage and direct the Postal Support mission. This office, called the Corps of Engineers Postal Construction Support Office (CEPCSO), was formed on 26 May 1971 by Corps of Engineers General Orders No. 14. CEPCSO was located in Washington, D.C., as part of the Military Construction Directorate in the Office of the Chief of Engineers. As part of the Directorate, CEPCSO could utilize the existing expertise of the Directorate's divisions; organizationally, its Chief, Brig. Gen. George A. Rebh, was Assistant to the Chief of Engineers for Postal Construction Support. In October 1972, CEPCSO was upgraded to the status of a directorate, becoming the Directorate of Postal Construction (DPC). Its functions as head and heart of the Postal Support mission were largely unaffected by this change in title.[7]

At the outset, the cooperative agreements of 11 March 1971 projected a CEPSCO role in both the preferential and bulk mail facilities construction, but with the maturation of the Postal Service Regions in 1972, the USPS turned over development of the preferential system to its fifteen Regional headquarters. Thus for all intents and purposes the CEPCSO role (and later, that of Huntsville Division) in Postal Support came to be limited to the Bulk Mail Centers only.

In CEPCSO's (and later, DPC's) structure, there were four main divisions: Design, Mechanization, Project Management, and Projects, Planning, and Reports. This table of organization broadly reflected CEPCSO's two major duties in the Postal Support mission. It was to manage the Corps of Engineers' effort which would be implemented through the Corps' subordinate division and district organizations, and it was to provide an interface between the Corps and the USPS at the Washington level for the bulk and preferential mail systems. In the realm of facilities design, CEPCSO's role was less than comprehensive. In general, it administered only the design of the postal structures and their site adaption, because the USPS preferred to retain control over the design of the internal layout and mechanization portions of its facilities. In its turn, USPS independently contracted most of the equipment layout and design for the Medium Bulk Mail Centers to the AE firm of Kaiser Engineering and that of the Small BMC's to Giffels and Associates. One of CEPCSO's major tasks was coordination of the design

and erection of housing for Giffels' and Kaiser's equipment and flow system designs. Eventually, CEPCSO designated six, then later ten, Corps geographic districts to carry out the AE management functions for the BMC structures. Local districts likewise carried out real estate acquisition, site work, and award of construction contracts for the buildings in conjunction with CEPCSO and USPS authorities. CEPCSO also provided technical assistance, consultation, and review for the USPS in engineering, installing, testing, and maintaining its mechanized equipment. Finally, CEPCSO was responsible for managing the procurement of standardized Government Furnished Property to equip the BMC's.[8]

A centralized procurement of standard items had not originally been envisioned for the Postal Support effort. For the Large BMC's at New York and Chicago, at least, the design of equipment and the production of drawings and specifications were done with the intent to include them in the construction contract. The construction contractor would then obtain the necessary equipment for his project, have it delivered to the BMC site, and install it as part of his total operation.[9]

Careful consideration of the scope of the Medium and Small BMC program, however, rapidly eliminated any chance of continuing this practice. Since the construction of the nineteen remaining BMC's entailed an enormous volume of equipment, a policy that allowed the contractor to handle procurement on a job-by-job basis raised the undesirable prospect of nineteen firms competing for one Government requirement. Obviously, a centralized Government Furnished Property program was highly desirable under these circumstances.[10]

A shift to GFP and a centrally managed procurement generated several advantages, the most persuasive being the savings that would result from a large volume procurement of standard items. Competition among construction contractors in the open market would be eliminated and costs held down by preventing free bidding for scarce items from forcing up their prices. In addition, procurement could be made sufficiently in advance of the award of the construction contracts to have long lead time items promptly available at scheduled progress intervals when the construction contractor needed the material for installation. This benefit in turn would shorten construction time, a point that the USPS found very attractive in getting the BMC's into operation as soon as possible.[11]

Once the decision for centralization was taken, a Corps division had to be selected to manage the procurement program. Five Corps geographic divisions, along with the Huntsville Division, were initially considered as the most likely candidates for designation as the central procurement office; by August 1971 General Rebh, Assistant to the Chief of Engineers for Postal Construction, had settled upon Huntsville Division as the best choice.[12] On 6 August 1971, General Rebh wrote to the Deputy SAFEGUARD Systems Manager to explain the Postal mission and to solicit permission to use the Huntsville Division in carrying it out. During the first week of October 1971, General Rebh visited Huntsville to discuss Division participation in the Postal mission, and shortly thereafter it was unofficially announced that the Division had been chosen to make the Postal GFP procurement for CEPCSO. The arrangement was made official by a letter to the Division Engineer of 26 November 1971.[13]

According to the 26 November assignment letter, Huntsville Division was to act "as the central procurement office for the Corps of Engineers to accomplish the procurement of fixed mechanization components for the Postal Service Bulk Mail System."[14] It was estimated that about $200 million worth of equipment would be required for the nineteen BMC's remaining in the program. Though not specifically stated in the letter of 26 November, the Division was also expected to procure the sortation equipment for the Large BMC at Chicago.[15] As revealed in later exchanges or correspondence, Huntsville Division was also to assure destination and delivery schedules, deal with warranties and defects, carry out in-plant inspection for quality assurance, manage contract files, monitor shipping damage, and carry out financial administration and payment to GFP contractors. As might be gathered, this was a procurement mission par excellence, and relatively little was demanded from Huntsville's Engineering or Construction Divisions.[16]

In announcing Huntsville Division's participation in the Postal mission, General Rebh said, "The selection of the Division was based on the widespread experience, expertise, and splendid reputation earned under the GFP procurement for SAFEGUARD."[17] This was indeed a succinct summation of the outstanding qualities that had led to Huntsville's selection, qualities that General Rebh knew well from firsthand experience as the Division's deputy division engineer in 1968. From the ABM program, Huntsville Division had gained considerable proficiency in standardization and acquisition of technical-industrial equipment, as well as assuring that these items arrived in a timely manner at scattered locations.

Its current workforce needed little augmentation, and the engineering talent coexisting with procurement at Huntsville was second to none in the Corps of Engineers.

For these reasons, assigning the Postal Support procurement to Huntsville Division was a natural move, but it was also an assignment that conflicted with the Division's monogamous marriage to the ABM program. Accordingly, the Division's relationship with SAFSCOM had to be modified in order to permit assumption of the Postal mission. This was done in a landmark "Memorandum of Agreement" between the SAFEGUARD System Organization and the Chief of Engineers dated 22 November 1971.[18] The Memorandum defined the Division's first divergence from the ABM mission, and asserted that the SAFEGUARD System Manager concurred in this divergence, provided that "the exercise of the postal procurement responsibility. . .will not interfere with the accomplishment of the Division's SAFEGUARD mission, which is specifically understood to have first priority." Further, "this exception [to the SAFEGUARD mission] does not constitute a precedent for further modification of the status of the Huntsville Engineer Division as dedicated to the SAFEGUARD mission." Naturally, the Agreement also provided that funding and personnel spaces for the Postal mission would be generated solely for resources other than SAFEGUARD's.[19] Subsequent ER 10-1-22 Division regulations incorporated the provisions of this Memorandum in the Division's working constitution.[20]

When the Postal mission began in late 1971, the New York and Chicago Large BMC's were already underway. Some procurement opportunities remained for the Chicago installation, however, and even before receiving official confirmation of its role on 26 November, the Division commenced the Postal mission by awarding a contract for this Large BMC alone. A bid package for the procurement of sack and parcel sorting systems for Chicago was issued on 5 November. The package covered the procurement, fabrication, and delivery of new equipment for five tray-type parcel sorting machines, two sack sorting machines, and the performance of other work, including the furnishing of operating and maintenance instructions to postal employees, required manuals, spare parts, and equipment parts lists. Contract DACW87-72-C-9000, the first in the Postal mission, was awarded for the above items to Speaker Motion Systems, Inc., of Milwaukee, Wisconsin, on 11 January 1972. The award amount was $2,506,000.[21]

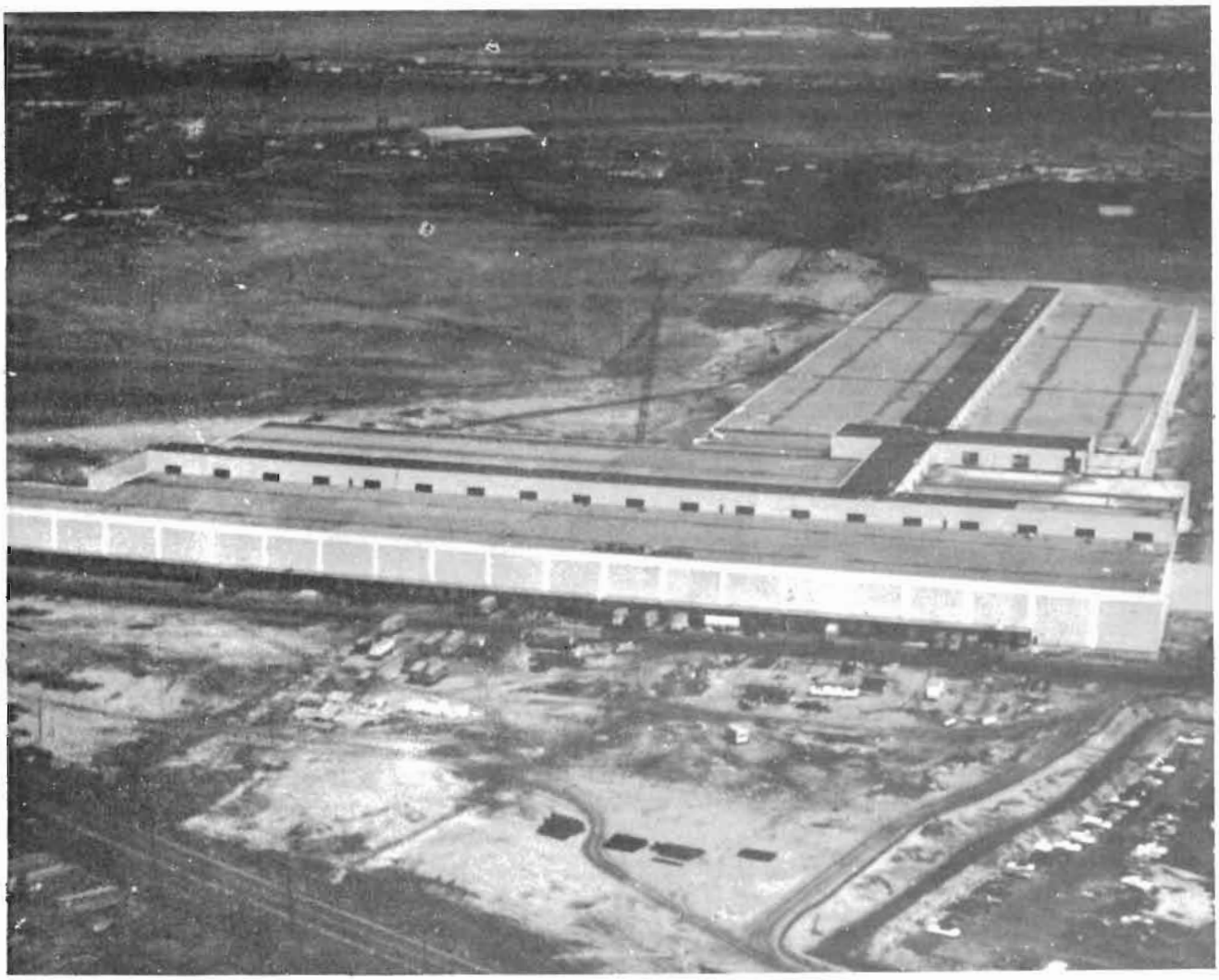
The award for the Chicago BMC in January 1972 was merely a warm-up for the vast Medium and Small BMC procurement that followed over the next four years. The quantity of material involved for these BMC's can only be described as immense. A partial listing included

--about 5,000 electric motors
--about 5,000 conveyor drives
--about 900,000 linear feet of belting
--53 sack shakeout units
--1,400 roller tables
--476 deflectors of three different types
--476 units of extendible conveyors
--632 units of metering rollers
--5,200 general conveyors
--174,000 square feet of slides
--44,500 chutes of five types
--3,800 container loaders
--42 container unloaders
--442 units of high speed parcel induction units
--19 computer systems

The total number of items to be purchased amounted to about two million; as noted earlier, the total value of these was initially estimated at about $200 million.[22]

The first step in the acquisition of the voluminous Medium and Small BMC procurement was to advertise it before prospective industrial suppliers and to publicize the procedures and conditions incumbent upon award winners. Towards this end a pre-solicitation briefing was held on 15 December 1971 in Washington, D.C. Notification of the briefing was widely circulated and 316 firms sent representatives to the meeting to hear presentations by General Rebh, Thor S. Anderson of the Huntsville Division, and officials of USPS. Attendees were provided with handouts describing a projected schedule for procurement, identification of procurement items, and other information relating to the bulk mail program.

Soon after launching the contracting process, the Division began to organize its resources for working administration of the Postal mission. In early 1972, Col. Henry K. Mattern was transferred to the Division's Executive Office as Special Assistant to the Division Engineer for Postal Activities. His duties included liaison with CEPCSO and assistance to the Division Engineer in Postal matters. Since the Postal mission was primarily a matter of procurement, the heaviest responsibility for execution fell to the Procurement and Supply Division headed by Thor S. Anderson. A veteran of more than twenty-five years in Government logistics, Anderson was also an "old-



*ONE of 21 US Postal Service Bulk Mail Centers, designed by the Postal Service and constructed by Corps of Engineers Districts. Central procurement of fixed mechanization components (CFP) for the system was accomplished by the Huntsville Division.*

timer" in the Huntsville Division, having joined during the formative SENTINEL period of 1967. The successful execution of the Division's GFP programs, both ABM and Postal, as well as later Saudi operations, were due in large measure to Anderson's experienced leadership. In 1971,early Postal activities were carried on by Anderson and the Procurement and Supply staff on an informal basis, but by 1 February 1972, a special two section Postal Branch had been set up with Roy E. Edwards as Acting Chief. Subsequent reorganizations in 1973 and 1974 produced a Postal Field Support Branch under Edwards and a Postal Contracts Branch under Benny G. Scott as Branch Chief. The Postal Contracts Branch had responsibility for bid solicitation, evaluation, contract award, and contract administration. The Postal Field Support Branch performed the GFP tracking function and served as the single GFP liaison point for the nineteen resident engineers in the field. The Postal Field Support Branch also handled the subscription mailing to prospective construction contractors for the BMC program. Both the GFP tracking and subscription mailing features of the Postal mission are described in more detail below. Staffing of the two Postal branches amounted to eighteen authorized civilian spaces, many of which were filled by internal transfer within the Division.[23]

The operations of Huntsville's procurement infrastructure were governed by the Armed Services Procurement Regulation (ASPR), the comprehensive multi-volume "bible" of approved Army purchasing procedures. In the case of the Postal BMC program, however, there was no precedent for a single division managing a centralized procurement of this magnitude for a civilian customer and one requiring interfaces with a number of other divisions and districts. Therefore, on 4 June 1973 OCE issued ER 1180-6-1, "Government Furnished Property for Postal Bulk Mail Centers," delineating responsibilities and procedures for inspecting, shipping, receiving, transferring, storing, and accounting for the GFP to be installed in BMC's. The regulation was applicable to all Corps of Engineers elements and field operating agencies in the BMC construction program.[24]

The procurement procedure for the BMC program was exceedingly complex. As noted above, the AE firms of Giffels and Associates and Kaiser Engineering under contract to the Postal Service had responsibility for designing the mechanization equipment that went into the BMC structures. While the Postal Service retained the total design responsibility, the Corps did the same for the procurement. While not actually designing the BMC equipment, CEPCSO's Mechanization Division coordinated drawings and specifications for the procurement of the GFP, reviewed mechanization designs and specifications, and supervised the integration of mechanization designs with building designs. In line with these operations, CEPCSO acted as the originating agency for Huntsville's GFP procurement packages. Working in conjunction with the AE firms of Giffels and Kaiser, CEPCSO furnished Huntsville Division with a list of articles to be procured, their quantities, the authorization to procure, item specifications, delivery dates and locations, data requirements, cost estimates, and necessary funds to accomplish the procurement.

The first and by far the greatest part of the GFP procurement for Medium and Small BMC's accompanied CEPCSO's assignment of the procurement mission to Huntsville Division in late 1971. This huge initial "shopping list" encompassed about twenty basic equipment items: various kinds of sack sorters, loaders, conveyors, shakeout units, sack holders, belting, motors and drives, slides, deflectors, computer systems, and so forth. Later, these twenty basic items were expanded to twenty-seven items comprising over two million deliverable articles. The twenty-seven items were broken down into ninety-six contract packages so that multiple awards might be made. This was done to avoid overloading any one supplier so that timely delivery could better be assured.[25]

Award of the contracts comprising the GFP for Medium and Small BMC's was spread over twelve months from 17 July 1972 until 29 June 1973, with several follow-on contracts extending to 5 December 1975. Most of the contracts after June 1973 were for miscellaneous additional items, quantities, or spares. The first Postal GFP award for Medium or Small BMC's was made on 17 July 1972 to Dyna Corporation, Dayton, Ohio. Under the provisions of this contract, Dyna Corporation was to supply the USPS facilities with four one-horsepower and thirty twenty-horsepower conveyor drive electric motors worth $4,100. The second Postal GFP contract was substantially larger: on 29 August 1972, the Ohio Rubber Co., Willoughby, Ohio, contracted to supply 56,075 ten-inch synthetic rubber impact cones molded around a steel insert bearing for $217,000. Over the ensuing weeks and months, ninety-four other Postal contract awards were made on an almost weekly basis, with most bid openings being conducted in the lobby of the SAFEGUARD Building Annex in Huntsville.[26]

Supervision of the flow of GFP items from factory to delivery site was an immense task performed by the Postal Area Support Branch under the term "GFP tracking." At the production end of the supply chain, each GFP contract required the supplier to submit an original production work schedule, monthly updates, and reports on the status of the contract. These schedules were reviewed, monitored, and administered for Thor S. Anderson, the Division's Contracting Officer in Postal affairs, by the Postal Area Support Branch. The supplier-furnished information became input into the data bank of a computer controlled inventory system, along with entries for delivery dates and locations. The automatic data processing software used for Postal activities was directly modified from that employed for SAFEGUARD's GFP inventory. Thus on short notice, at any time it was possible to ascertain the status of any GFP contract that had been awarded since the beginning of the program. In practice, the "tracking" function entailed frequent telephone conversations and plant visits to sort out production bottlenecks, damage or loss in transit, and proper transfer to the construction contractor at each site. It should be noted that quality control on the manufacturer's premises prior to shipment was delegated to personnel of the Defense Contracts

Administration Services (DCAS) acting in a procurement quality assurance role. Reimbursement to DCAS was on the basis of .47 manhours of effort per thousand dollars of contract value.[27]

The GFP delivery dates were specified by CEPCSO simultaneously with the original procurement requirement and authorization. The GFP supply contract delivery date was, in fact, a thirty-day "window" consisting of an early date ("not to be delivered earlier than") and a late date ("not to be delivered later than). There existed, in most cases, a thirty-day span between the supply contract late-date and the construction contract late-date. The latitude was provided as a cushion to insure that the GFP would be received at the construction contract site well before its moment of need, to minimize interference with construction schedules due to late deliveries, damage, or other unforeseen problems.

At the delivery end of the supply chain, "tracking" required the verification of prompt and safe delivery of GFP material at any given site. In the case of the Postal program, this was done by the Resident Engineer or his authorized assistant at the construction site. Upon the recommendation of the local District Engineer, Huntsville Division designated the Resident Engineer as Contracting Officer's Representative (COR) to administer GFP field actions. In the event of inexcusable untimely delivery of equipment, the GFP contracts called for assessment of actual damages rather than liquidate damages against the supplier. This provision was included to encourage supplier to make timely delivery because of the magnitude of financial damages that the USPS would suffer if the bulk mail network did not go into operation when scheduled.[28]

Not surprisingly, the Postal GFP procurement encountered several snags as it matured. A large percentage of GFP was delivered late when compared with the original contract delivery date. The percentage of GFP delivered late **contractually,** however, was approximately one percent. This figure included the effect of excusable delay factors, such as the impact of USPS-AE design deficiencies and continuous technical changes. As an example of the technical changes, the five general and incoming conveyor contracts for items critical to the mechanization system showed an average of approximately 100 changes per month for almost eighteen months; in October 1973, 27 percent of the original contract drawings had been revised, which necessitated 416 modifications to fifty-five contractors. This trend continued throughout a major portion of the program. Additionally, in some sectors such as the conveyor and rubber belting industries, the huge sudden demand of the BMC program stressed or exceeded the capacity of specialized manufacturers, leading to rather less output than USPS originally expected. Other delays stemming from "acts of God" or acts of man--accidents, strikes, breakage or loss in transit, improper handling or storage, weather conditions, and material shortages-- were common to any procurement and had no exceptional impact on Postal GFP.[29]

In addition to fulfilling the "GFP tracking" function in procurement, the Postal Area Support Branch was also charged with a major task in supporting the Postal BMC construction bidding process. This responsibility, which was quite separate from the procurement operations of the Branch, involved supplying diverse USPS authorities, Corps geographic districts, and especially prospective construction contractors with certain mechanization equipment drawings and specifications available at Huntsville Division. In carrying out this assignment, Postal Area Support Branch Chief Roy Edwards developed the concept of "subscription mailing" which became one of the most notable innovations of the Procurement and Supply Division's Postal activities.[30]

At the prompting of the Postal equipment AE design firms Giffels and Kaiser, OCE decided that one agency should control all of the mylar master mechanization equipment drawings for BMC's. This unity, it was thought, would ease control of ensuing modifications and also expedite distribution of copies to elements that needed them. Because CEPCSO was already handling the review of equipment design, it might seem logical that the mylar masters should have remainded under Washington's control. However, CEPCSO lacked the sheer capacity or experience to duplicate, mail out, and continually update the mass of drawings associated with the program. Huntsville Division, on the other hand, possessed all these qualities because of SAFEGUARD. Also, as managing office for the GFP procurement, Huntsville Division already had possession of the written equipment specifications which were included as Section "F" of each GFP contract. For these reasons, under OCE Engineering Circular EC 1180-6-4, Huntsville Division was made the "office of record" repository for custody, reproduction, and issuance of the mylar master equipment drawings, installation drawings, and specifications associated with GFP

equipment.[31]

By the time that "subscription mailing" fully matured, Huntsville Division was controlling and issuing four categories of GFP-related materials; standard mechanization equipment drawings, standard mechanization installation drawings, site peculiar mechanization equipment drawings, and mechanization equipment specifications. These documents served several purposes. In procurement the GFP equipment drawings and specifications served to guide contracting, manufacture, and assembly of components. But in addition to their procurement and manufacture role, the mechanization drawings and specifications were also vital to the construction bidding, erection, and construction supervision process. Only with the help of GFP drawings and specifications could an architechtural AE firm present a building design proposal. Only with GFP drawings and specifications in hand could a prospective construction bidder derive the structural configurations, finishing instructions, and what hardware was not provided as GFP. A host of placement, installation, and interface data came from the installation drawings. These drawings and specifications were equally essential to Corps district personnel in the resident engineer offices who had to oversee the construction process after contract award.

"Subscription mailing" was Huntsville Divison's answer to the need to distribue the GFP drawings, installation drawings, and specifications to nineteen districts and more than one hundred construction firms interested in building BMC's. At the heart of the "subscription mailing" system was a series of mailing address lists maintained in the Postal Area Support Branch made up of those construction firms and official agencies that wished to obtain drawings and specifications. As BMC IFB's were issued site-by-site, construction bidders were advised through notices in the construction solicitation that they might obtain needed GFP drawings and specifications from Huntsville Division, together with the costs. Upon receipt of a request from a bidder, the firm's name was entered on a "subscription mailing" list to immediately receive a complete up-to-date set of standard drawings, the site peculiar drawings applicable to its need, and one set of associated specifications. Later, as modifications flowed in from Washington, revised drawings incorporating changes went out to all those entered on the lists. Once a firm or agency was entered on the "subscription mailing" list for a particular set of drawings, that entry would be in a position (drawing-wise, at least) to competitively bid on all subsequent BMC's.

The fees established for "subscription mailing" were modest and were never intended to defray reproduction costs. A subscription for installation drawings could be had for $100; a subscription to standard equipment drawings ran $150; a set of site peculiar drawings and associated specifications were $15. Total costs for the subscription mailing for the Small and Medium BMC's was $441,816.00, excluding small costs for the Washington BMC which was handled separately.[32] In addition to construction firms with paid subscriptions, the Huntsville Division also mailed out large quantities of "freebie" drawings to Corps districts, structural AE firms, and various USPS authorities. In the spring of 1978 Roy Edwards personally estimated to the author a tentative "ballpark" figure of about 400 tons total weight for all mailings. Careful tailoring of the reproduction to quantities required resulted in less than 5 percent surplus after the mailing terminated.[33]

At the inception of the BMC program, drawings, for the Chicago Large BMC were handled on an ad hoc basis by Intra-Army Directives from Washington to Huntsville Division rather than on a subscription basis. A policy of "subscription mailing" was instituted with the Washington, D.C., BMC and evolved through three phases. The Washington BMC was the progenitor of the nineteen BMC's and was treated separately because there was a time span of ninety days between it and the next BMC IFB for Atlanta. The second phase was "subscription mailing" for the remaining thirteen Small BMC's, and the third was for the five Medium BMC's.

Because of delay in final design by the AE, Huntsville was compelled to issue standard equipment drawings and specifications for the Washington facility that were incomplete or outdated. They were issued in a deficient state so that construction bidders would have something, however inadequate, on which to base their proposals. The Washington "subscription mailing" did not contain the standard installation drawings or the site peculiar installation drawings.

Mailing for the remaining Small BMC's, although more complete, was still inadequate in some areas because the design of GFP components had not yet been formalized. The later the bid opening for a particular BMC the more complete the drawings became. Data for the Small BMC phase consisted of standard mechanization equipment drawings, standard mechanization installation drawings, site peculiar mechanization drawings, and mechanization equipment specifications.

The mailings for the five Medium BMC's of the last

phase differed from the above in that the standard mechanization installation drawings for the five centers were site peculiar. Since the five Medium BMC installations were not de facto standard, each geographic district bidding a BMC controlled the mylars and reproduced them to support their individual bid initiation. Huntsville supplied only standard mechanization equipment drawings, site peculiar mechanization drawings, and equipment specifications for the Medium centers.[34]

Because of contractual ramifications involving the drawings under "subscription mailing," Huntsville Division maintained detailed records to establish the exact level of amendment existing in the GFP drawings and specification sheets at the point of construction contract award. These records covered all mailings, and the Division could trace each drawing and specificiation sheet to find the revision level, amendment level, modification level, date of mailing, and identification of those who received the mailings. This degree of record-keeping substantiated the Government's legal position so soundly that no contractor chose to contest claims on the basis of obsolete information supplied by GFP drawings or specifications. The Division, of course, was not responsible for design errors or inconsistencies upon which some claims might have been based.[35]

As in SAFEGAURD, there was a special "after action" report prepared within Huntsville Division concerning the Postal mission. This report contained a section entitled "Lessons Learned." One of the most significant lessons learned was that the planned procurement and production lead-time and determination of the requirements of GFP must be adhered to and furnished to the procuring agency within the announced schedule. The failure to do so could result in stretch-out of the overall program. Technical problems, increased costs, and delinquent deliveries can also be anticipated as forced trade-offs for compressing production and/or procurement lead-time.[36]

An old saying has it that "the proof of the pudding is in the eating." The best proof of the quality of the GFP procurement program could be found in the timely delivery of GFP and in the cost advantages accruing to the USPS when the "bottom line" was calculated. Original estimates for the mechanization equipment had been in the vicinity of $200 million, but final GFP contract awards, including all modifications, at the time of close-out totalled less than $173 million, despite continuing inflationary tendencies of the period.[37] Furthermore, after auditing the procedures used by Huntsville Division during 1973--by which time sixty contracts worth $141,529,805 had been issued--the U.S. General Accounting Office concluded:

> HND had adopted a good management approach for the postal GFP procurement. Because of the tight schedules and the massive coordination required, the normal management by exception probably would not have been successful. The procedures and controls adopted to monitor the performance of the contractors are good.
>
> Although some cost growth has occurred, the cost increases have, for the most part, been caused by design changes, which were beyond HND's control. The procurement method of primarily advertised fixed price contracting and dividing large procurements among several contractors based on contractor capability and bid price was good. Bidder response seemed adequate in most cases. In those cases where bidder response was lacking, HND took appropriate steps to increase bidder response.
>
> The late receipt of design packages [noted above, "Lessons Learned"] and many contract supplements appear to have contributed to delivery delays. However, delays do not appear to be significant at this time, with the exception of conveyors and chutes. These items are being delayed for a variety of reasons, many of which appear to be beyond the control of HND. . . .
>
> The lines of communication between HND, COE [sic, OCE], and USPS appear to be effective. Coordination and cooperation seem to be good, and all parties to the procurement appear to be kept informed on the status of the procurement.
>
> In summary, although some minor cost growth and schedule slippage have occurred, at this point, HND appears to have managed the postal GFP procurement well.[38]

## II. The NASA Space Shuttle Mission and Other NASA Projects

In May 1972 Huntsville Division assumed the second of its missions beyond the SAFEGUARD System, a commitment to support the National Aeronautics and Space Administration (NASA) through design and construction of test facilities needed for the Space Shuttle. The agreement with NASA subsequently evolved into a four year program including about fifteen Space Shuttle engineering

design and construction contracts worth about $30 million. After the Space Shuttle projects got underway, the Division also performed several smaller miscellaneous tasks for NASA that were not directly related to the Shuttle, such as storm damage repairs to the Marshall Space Flight Center Headquarters Building on Redstone Arsenal. Though less imposing in engineering terms than SAFEGUARD and less significant financially than the Postal procurement, the Division's NASA-related activities still represent a notable part of the Division's work load during the period 1972-1976.

When Huntsville Division joined the Space Shuttle effort in May 1972, the program was already two years old. Early in 1970, NASA's Office of Manned Space Flight had turned its attention to realizing the design and development of a large payload manned spacecraft that could economically serve as a cargo carrier for Earth orbit missions during the 1980's. The chief criteria for the craft that came to be dubbed the "Space Shuttle" were a large useful payload, low operating costs, and ultra-reliable flight characteristics. The vision was that of a veritable space cargo truck capable of making repeated shuttle trips back and forth into orbit. As President Nixon expressed it when authorizing a Shuttle "go-ahead" on 5 January 1972,

> this system will center on a space vehicle that can shuttle repeatedly from Earth to orbit and back. It will revolutionize transportation into near space, by routinizing it. It will take the astronomical costs out of astronautics. In short, it will go a long way toward delivering the rich benefits of practical space utilization and the valuable spinoffs from space efforts into the daily lives of Americans and all people.[1]

The "rich benefits" mentioned by the President were astounding. They included the ability to recover, repair, and adjust the paths of satellites already in orbit; to take a quantum jump forward in the number, weight, and complexity of orbiting experiments; to make possible exotic manufacturing in a space environment; to obtain a ready rescue capability for endangered astronauts; to enable the assembly of the first permanent manned space stations from components brought up in stages.

As President Nixon announced the program, NASA engineers were busy making the vehicle a reality. On 26 July 1972, North American Rockwell Corporation's Space Division at Downey, California, was chosen as prime contractor for design, development, and production of the Orbiter Vehicle and its integration with other elements of the Shuttle system. As it has emerged from North American drawing boards, the Space Shuttle configuration is that of a delta-winged, fat-bodied cross between a rocket and an airplane about the size of a DC-9 airliner. Incorporated into the tail of the Orbiter Vehicle itself are three Rocketdyne Space Shuttle Main Engines (SSME) generating 470,000 pounds of thrust each; during the launch phase these engines are fed liquid hydrogen ($LH^2$) and liquid oxygen (LOX) from a single simple cylindrical External Tank half again as long as the Orbiter itself. Having supplied the "piggy-back" Orbiter engines from lift-off into orbit, the External Tank is jettisoned to fall free while the Orbiter continues its space mission.[2]

Despite their total thrust of 1,410,000 pounds, the Shuttle's liquid rocket engines are totally incapable of lifting the vehicle's weight without assistance. Most of the boost effort during the launch phase is made by the two Solid Rocket Boosters (SRB) manufactured by Thiokol which, at 3,521,000 pounds of thrust each, are the largest such solid rocket motors ever made. The motors are attached to the flanks of the External Tank underneath the Shuttle and are cast off after burn-out to be parachuted back for reuse.[3]

As prime contractor, North American Rockwell was responsbile for testing the Orbiter Vehicle's airframe and flight characteristics in conjunction with NASA. NASA's Marshall Space Flight Center (MSFC) at Huntsville was charged with partial or complete testing of the Orbiter's liquid fuel SSME, the External Tank, and the SRB. The Orbiter's liquid fuel engines were to be test-fired at NASA's National Space Technology Laboratory (NSTL)[4] at Bay St. Louis, Mississippi, an isolated location about twenty miles inland on the Pearl River that had previously seen comprehensive engine tests for the earlier Saturn series of rocket engines. Structural tests on the Shuttle's External Tank and on the SRB were to be performed at the MSFC. These structural tests meant anchoring the test articles in specially-designed test stands and subjecting them to simulations of the static and dynamic stresses that they would encounter in actual use.

In testing components of the Shuttle, NASA determined that the most economical approach would be to modify existing facilities such as the former Saturn engine stands standing idle at Bay St. Louis rather than to build new facilities. Assistance in technical design and construction of these modifications was a natural mission for the Army Corps of Engineers in general and for Huntsville Division in particular. The Division was experienced

in missile work for the SAFEGUARD System and conveniently collocated with the MSFC in Huntsville; many Division employees had also participated in the design and construction of the original Saturn facilities at both MSFC and NSTL as members of Mobile District. Informal converstions for a NASA mission were conducted during the spring of 1972, and cementing of the NASA-Corps connection was officially announced in May 1972. Written concurrence of the SAFEGUARD System Organization releasing Huntsville Division for support of the Space Shuttle came in a "Memorandum of Agreement" dated 8 June 1972. As with the Postal procurement agreement with SAFSO in November 1971, the NASA mission Memorandum also stipulated that for operational control the "Space Shuttle Program responsibilities are exceptions to the provisions of existing agreements between the Chief of Engineers and the SAFEGUARD System Manager... [which] do not constitute a precedent for further modification of the status of the Huntsville Engineer Division as dedicated to the SAFEGUARD mission."[5]

Organizational accommodations for the conduct of the NASA mission were relatively simple. Shortly after assumption of the mission in May 1972, Lt. Col. J.J. Cook was assigned to the Executive Office as a Special Assistant to the Division Engineer for NASA Activities. Joe G. Higgs, former Site Development Section Chief, Civil Engineering Branch, Engineering Division, was made NASA Project Manager. By the end of 1972, Higgs headed a one-man NASA Project Office under the Project Management Branch of the Engineering Division. During 1973 the NASA Project Office grew to two, and Higgs was succeeded by C.R. Thomas as Section Chief. The Project Office monitored criteria development and final design and provided technical supervision of construction contract packages. Engineering support and management for construction came under a three-man NASA Construction Office in the Construction Division that was physically located in Bldg. 4371 at the MSFC. Everitt W. Martin became Chief of the NASA Construction Office in 1973. Since the NASA work was predominantly engineering design and construction, no special organizational changes were warranted in other Division offices.[6]

Because extensive contruction was anticipated at the NSTL, along with some lesser activity at the nearby Michoud Assembly Facility outside New Orleans, a joint area office with a staff of about a dozen was opened at NSTL on 17 November 1972. Personnel assigned commuted to supervise jobs at both the NSTL and at Michoud. The first Area Engineer was John J. Blake, formerly Resident Engineer at the Grand Forks, North Dakota, SAFEGUARD MSR site, who served until July 1973. Blake was succeeded by W.F. Jebb on 25 November 1973; Jebb was followed by E.L. Taylor on 23 June 1974. Construction activities at the MSFC in Huntsville were supervised directly by NASA Construction Office located on Redstone Arsenal but organizationally attached to the home office.[7] The tasks undertaken at each of these three locations provided a convenient framework for describing Huntsville Division's NASA mission, and the **History** will briefly consider in turn Corps activities at the NSTL, followed by Michoud and the MSFC.

At the NSTL, Huntsville Division worked closely with NASA between 1972 and 1976 on four major construction contracts totalling about $16.5 million. Here, on an isolated Government reservation in the Pearl River Swamp, NASA wished to modify three existing test stands remaining from the Saturn program for test firing of the Space Shuttle Main Engines (SSME). Two of the stands designed A-1 and A-2 were old Saturn II facilities to be modified for single engine tests of the reusable $LH_2$-LOX fueled SSME. Stand A-1 was intended to simulate low altitude flight conditions and Stand A-2 to simulate high altitude flight, the high altitude Stand A-2 differing from its companion in that the engine was to be mounted at an angle of 18 degrees from the vertical and by the addition of a diffuser system through which the engine exhausts. The diffuser system serves to reduce back pressure, thereby imitating the operating conditions found at about 70,000 feet. The third structure, Test Stand B-2, was an old Saturn S-IC facility formerly used for acceptance testing; as Phase I of two contracts used for acceptance testing; as Phase I of two contracts, NASA wanted to convert this stand to accept a cluster of all three SSME in their final Orbiter configuration. Under a separate Phase II contract, modifications to Test Stand B-2 also included construction of off-site docking facilities and a turning basin to handle the barges carrying $LH^2$ and LOX.

NASA and Huntsville Division began NSTL work by contracting the modifications to Stands A-1 and A-2 needed early in the SSME testing program. For Test Stand A-1, NASA had already contracted with the AE firm of Sverdrup & Parcel & Associates, St. Louis, Missouri, for design engineering of the modifications, and Huntsville had only to monitor this contract. Actual construction at Bay St. Louis was begun by the issuance of an IFB for modifications to Stand A-1 on 16 August 1972. Distribution of this IFB included 166 sets of drawings and 196 sets of specifications mailed

to seventeen prequalified prime contractors. At the bid opening in Huntsville's Sheraton Motor Inn on 26 September, Industrial Contractors, Inc., Idaho Falls, Idaho, was found to have the lowest of nine bids received. Contract DACA87-73-C-9002 in the amount of $2,942,949 was subsequently awarded to Industrial Contractors on 16 October 1972.[8]

Under the terms of their contract, Industrial Contractors were to extensively modify the existing stand, along with its piping and work platforms, to accept one SSME in a vertical firing position. New vacuum-jacketed $LH^2$ and LOX tanks, oxidizer tanks, thrust measuring systems, new controls and bay equipment to monitor engine performance were to be installed. New fire extinguishers, flame deflectors, and repainting rounded out the revisions. The project was due for completion by 22 November 1974, and it was accepted by NASA on that date. The final cost, after fifty-seven revisions to the original contract, was $3,616,793.[9]

Remodelling of companion Test Stand A-2 followed about eight months after Stand A-1. In fact, the first NASA contract awarded by the Division, DACA87-73-C-9001, went to Sverdrup & Parcel for AE services on Test Stand A-2 on 29 September 1972, or two weeks before the construction contract award for Stand A-1.[10] A construction contract for Stand A-2 work was awarded to Industrial Contractors on 22 June 1973. Originally worth $4,169,699, this contract ultimately grew to $4,265,355 by the time of acceptance on 8 July 1975. Construction changes were similar to Stand A-1 except for the addition of a diffuser which moved the engine, propellant tanks, and other equipment upward about eight feet.[11]

As part of their contracts for Stands A-1 and A-2, Industrial Contractors were expected to supply the materials installed in the course of construction. A notable exception, however, was made for the vacuum-jacketed, stainless steel 110,000 gallon $LH^2$ and 40,000 gallon LOX fuel tanks that represented the most significant items on the modification agenda. These tanks were expensive, sophisticated, long-lead procurement items, and NASA preferred to retain control of their design and supply through its own GFP contracting. Accordingly, NASA awarded contract NAS8-29323 in the amount of $1,058,880 for Test Stand A-1 tanks to Pittsburg-Des Moines Co. on 25 October 1972; the contract was then released to Huntsville Division for further supervision. Under Division management, a contract option was exercised during FY 1973 for a second set of tanks for Stand A-2, thus bringing the total for contract NAS8-29323 to slightly more than $2 million.[12]

The third test stand to undergo modification at Bay St. Louis, Test Stand B-2, was a structure intended for the later stages of the SSME testing program when the final configuration of three coupled engines was to be fired. Hence, contracting for Test Stand B-2 came later than for Stands A-1 and A-2; it did not get underway, in fact, before early 1974. The operations performed on Stand B-2 were also more far-reaching than for either A-1 or A-2. In addition to modifying the Test Stand proper, NASA also wanted to enlarge the barge turning basin terminal at the foot of the stand and to build docking facilities for the unloading of the cryogenic liquid propellants. The disparate nature of the work, along with scheduling and other considerations, prompted separate Phase I and Phase II construction contracts. The design engineering, however, for both Phase I and II was done under a single AE contract (DACA87-74-C-9001) with Sverdrup & Parcel for $109,314.[13]

Since it was less prone to construction snags and was needed to facilitate incoming water-borne shipments of large pieces for remodelling the test stand, the off-stand Phase I was undertaken first. A contract for Phase I (DACA87-74-C-9002) in the amount of $1,988,000 was awarded to Algernon Blair Industrial Contractors, Inc., of Atlanta, Georgia, on 7 February 1974. It was completed on 6 September 1975. An interesting feature of Algernon Blair's approach was the election to build the docking facilities on dry land, then to enlarge the canal basin by dredging material away from the dock and surrounding areas.[14]

Modifications to Stand B-2 itself were started on 18 October 1974, when Industrial Contractors, Inc., were awarded their construction contract at the NSTL. The contract, DACA87-75-C-9003, was worth $7,429,069, making it by far the largest in the test stand series. The substantial sum was warranted by the extensive structural revisions required to accommodate the Main Propulsion Test Article (MPTA), comprised of three flight-rated SSME in their final Orbiter configuration, a structural truss simulating the Orbiter Vehicle, and an External Tank. Industrial Contractors was to remove the entire upper 100 foot superstructure of the test stand above the existing booster support frame, along with a portion of the existing booster support frame. These areas were completely rebuilt to the new configuration required for the MPTA. Unlike Stands A-1 and A-2 which incorporated fuel tanks in the course of modification, the $LH^2$ and LOX supply for MPTA runs on Stand B-2 came from an actual Shuttle External Tank mounted on the Stand as it would be on

the flying Shuttle.[15]

*TEST STAND B2, "Main Propulsion Test Article" stand extensively remodeled at NSTL.*

In carrying out the engine stand modifications, Industrial Contractors made extensive use of off-site fabrication procedures. The existing canal channel from the Pearl River to the foot of the stands made water transport of the heavy prefabricated components convenient and economical. Thus off-site fabrication enabled large structural members to be completely assembled many miles away, floated to the job site by barge, and lifted directly into position on the test stand as complete units. Hoisting equipment presented no great obstacle, since the construction contract allowed the contractor to utilize existing derricks mounted on top of the stands. These cranes provided capacity to lift and set one-piece structural sections weighing up to 200 tons. Piping, ladders, platforms, and miscellaneous fittings not already installed on the structural sections at the fabricator's shop could be installed on the ground beside the stand before the piece was lifted into place. Major lifts often required planning several weeks in advance of the lift because of complicated rigging, narrow clearances, and so forth.

The prefabricated approach was not without its difficulties. One that could have been anticipated was that the complex prefab components did not always fit into the places intended for them. Adjustments had to be made before the components could be mated. The situation was further compounded by NASA subcontractors performing maintenance and refurbishment in the same general area as the new construction, leading to a need to coordinate activities in the interests of efficiency and safety. Finally, as engine development continued apace, test criteria changed, producing subsequent contract modifications. The modifications produced little real delay in completion, however, and all the engine stands were ready when needed, even though this was four months early in the case of Stand A-1 and six months early for Stand A-2. The A-1 Stand went into operation on 19 May 1975 with the first NSTL firing of the SSME; Stand A-2 saw its first Shuttle test firing on 31 March 1976; tests on Stand B-2 were schedule to begin in December 1977.[16]

At Chalmette, Louisiana, thirty-five miles southwest of the NSTL, lies NASA's Michoud Assembly Facility, a collection of cavernous buildings used during the Saturn program for assembly of huge stage components. As part of the Shuttle program, NASA desired to resurrect the facility for production of the 206-foot long External Tank. This need entailed a revamping of parts of the Facility. The majority of these activities were carried out under NASA-administered contracts and are of no concern here, but Huntsville Division was requested to design and construct the modification and rehabilitation of the air conditioning and dehumidification system for the main fabrication building. Design of the air processing system changes was awarded to the New Orleans AE firm of Cappel, Tousley & Moses under contract DACA87-73-C-9004 on 29 December 1972. Construction began on 29 June 1973 under a $529,480 contract (DACA87-73-C-9004) awarded to Babst Services, Inc., Metairie, Louisana. Corps contract supervision for the Babst contract was performed from the Bay St. Louis Area Office; the modifications were completed on 1 September 1974 and accepted by NASA on 10 October 1974.[17]

The third focus of Huntsville Division's NASA-related activites was the Marshall Space Flight Center on Redstone Arsenal at Huntsville. The MSFC was the original home of the American space program, and despite dispersion to Houston and Mississippi, in the mid-1970's it still remained NASA's single most important test complex. NASA planned to utilize existing MSFC facilities for most of the structual testing of the Shuttle's Enternal Tank, its SRB motors,

and of a complete Shuttle vehicle assembly in flight configuration. As at the NSTL, this most economical of test program options still required considerable remodelling, refurbishing, and some new building. At the MSFC, therefore, Huntsville Division carried out five important Shuttle test facility construction projects worth about $10,000,000 between 1973 and 1976. Additionally, during the same period the Division managed three other contracts for NASA that were not related to the Shuttle program. These three non-Shuttle projects offer considerable interest of their own and will be described following the Shuttle facilities.

Of the five Shuttle-related projects conducted by Huntsville Division at the MSFC, the first two can conveniently be grouped together by virtue of their chronology and nature. Both projects came early in the NASA mission -- the construction contracts in February 1973--and neither project was concerned with the Shuttle structural test facilities that were built much later. The first NASA-Huntsville Division undertaking at the MSFC was a result of NASA's need to obtain acoustical parameters for the SSME before the main series of developmental tests were run. NASA believed it could derive the information sought by extrapolation through a series of 1:40 scale model engine tests. A test facility for operation of the small engine already existed in the Acoustic Model Engine Test Facility (MSFC Bldg. 4540), but modifications were needed to accommodate the subscale SSME. For this job, NASA engaged the AE firm of H.J. Ross to design the modifications while handing over construction contract responsibilities to Huntsville Division. On 6 February 1973, the Division awarded construction contract DACA87-73-C-9005 for $1,969,269 to Industrial Contractors, Idaho Falls, Idaho, the lowest of ten bidders. Over the next eighteen months, Industrial Contractors revised the Acoustic Model Engine Test Facility's structure and installed new gaseous hydrogen and nitrogen pressure systems, a $LH^2$ system, and various ancillary support systems. Subsequent to the initial February 1973 award, a major Change Order "BO" was appended for work on Bldg. 4659, the High Pressure Gaseous Propulsion System Support Building. This change order called for construction of a compressor building, vaporization shed and burn stack, and several hundred yards of pipeline connecting the compressor building and test stand. After Change Order "BO" and twenty others worth an additional $1,088,947, the Acoustic Model modifications were accepted by NASA on 6 August 1974.[18]

Concurrent with the Acoustic Model Engine Test Facility project, Huntsville Division also awarded and administered a NASA-designed addition to the MSFC Hazardous Operations Building housing the Electrical Power Laboratory. The addition provided laboratory space for research, development, and evaluation of electrical power generation devices and integration of electrical systems associated with the Space Shuttle program. This project, contracted to Bryson Construction Co. of Decatur, Alabama on 20 February 1973, had an original award value of $268,400. During the ten month construction period, Bryson Construction added a 6,500 square foot concrete masonry addition complete with air conditioning, heating, and power to the existing Hazardous Operations Building. The addition was accepted on 24 January 1974.[19]

More than eleven months elapsed during 1974 between completion of the Electrical Laboratory Addition and the commencement of further Corps-directed Shuttle construction at the MSFC. During this period, the Division was engaged in two non-Shuttle tasks that will be described later: installation of a chiller system in Bldg. 4487 and repairs to Bldg. 4200. When Huntsville Division resumed Shuttle-related construction at the Center, it was on a series of three kindred projects intended for the Shuttle's structual testing program. With a total original contract value of about $6,842,000, these three corstruction contracts represented a large chunk of the Division's NASA mission.

It will be recalled that the Space Shuttle's External Tank performed highly important dual functions in fueling the Orbiter's three SSME as well as tying the Orbiter and the two SRB motors together. This "piggy-back" configuration imposes great static loading of the External Tank from the time the SRB motors, Orbiter, and Tank are mated through the roll-out to the launch pad and especially during the launch phase of the mission. These static loads are compounded by the aerodynamic forces and bending moments acting on the Shuttle in the ascent of the flight until the External Tank is released from the Orbiter after attaining orbit. These factors, coupled with the stringent requirement for minimum weight, dictated the need for a careful ground structural test program.

The External Tank consists of three major elements: a $LH^2$ tank, a LOX tank, and an intertank structure joining the two. The Structures and Mechanics Laboratory at the MSFC, modified in FY 1973 to accommodate the testing of major Shuttle components, was adequate and could be used for structural testing of the LOX tank and intertank

structure. Because of its size (approximately twenty-six feet in diameter, 113 feet long) and because NASA intended to test the tank filled with 53,800 cubic feet of $LH^2$, the vessel requires a very large test facility with a suitably removed location. An existing ten-year old Saturn S-IC stage engine test stand (Bldg. 4670) could, with modifications, provide the capability to test the $LH^2$ tank.

During 1973 NASA engaged the AE firm of Norman Engineering to design the conversion of the Saturn engine stand into a structural test facility, and in 1974 the Agency turned to the Huntsville Division to conduct the construction phase. IFB's for the job were issued to eight prequalified firms on 8 August 1974; three bids were received with Algernon Blair Industrial Contractors, Inc., Atlanta, Georgia, the low bidder. On 4 November 1974 contract DACA87-75-C-9004 in the amount of $3,821,000 was awarded for External Tank modification to the S-IC stand. Algernon Blair's primary responsibilities included relocating the stand's flame deflector, augmenting the adjacent $LH^2$ storage capacity, installation of $LH^2$ transfer and disposal systems, modification and rehabilitation of the high pressure gaseous and water systems, modification to the service platforms and structural members, modifications to and extension of the electrical and mechanical utilities, and procurement and installation of hydrogen instrumentation and control system in the Test Control Center and on the stand. After thirty contract changes worth an additional $229,213, the facility was accepted by NASA on 9 July 1976. The non-delivery of stainless steel vacuum-jacketed pipe delayed completion by about ten weeks.[20]

Just as the External Tank required a structural test program to verify its design criteria, so too did the SRB motors. Not only did these have to resist a generated thrust of 3,500,00 pounds, but the casings were expected to survive a useful life of ten firings, including parachute descents from the upper atmosphere and subsequent recovery operations. As with other aspects of Shuttle testing, NASA believed it could modify a facility left over from previous programs to handle the SRB testing. In this instance, the Agency chose Bldg. 4572, a facility originally built for the Redstone rocket nearly twenty years before and since used for succeeding generations of rockets. For the Shuttle's SRB, it was necessary to modify the structure to apply static and dynamic loads with the SRB lying horizontally.

NASA requested that Huntsville Division conduct both the design and construction of the modification to Bldg. 4572. The engineering design contract, performed by Connell & Associates for $86,500, was awarded on 9 October 1974 and completed on 15 May 1975. A contract for construction of the necessary revisions in the amount of $1,097,552 was awarded on 18 July 1975 to Harold Construction Corporation of Huntsville, with completion schedule for 1 April 1977.[21]

*"SPACE SHUTTLE MATED GROUND VIBRATION TEST FACILITY" (Building 4450 Marshal Test Center) converted for Space Shuttle Testing.*

The third MFSC structural testing facility updated by joint NASA-Corps effort was Bldg. 4550, a former Saturn V dynamic test bed that the Agency wished to convert into a Space Shuttle Mated Ground Vibration Test Facility. The somewhat awkward name was a good clue to the building's function. In it NASA intended to subject an actual Orbiter Vehicle assembled with all components to dynamic stresses reproducing those that would be found in flight, including strong vibrations. Even though Bldg. 4550 was the tallest building at the Center, and one of the tallest in northern Alabama, the conversion required broad structural modifications to enlarge the existing test bay from fifty feet by fifty feet to seventy-four feet by seventy-four feet of all clear space (the Orbiter's

wingspan is about seventy-nine feet). The 175-ton derrick on the test stand also had to be relocated as part of the bay area expansion, along with changes to the electrical, mechanical, and instrumentation systems. For this project NASA preferred to retain control of design engineering functions, but the Agency requested that the Corps of Engineers conduct the conversion construction. To this end, Huntsville Division invited bids during July 1975 and on 15 September awarded construction contract DACA87-76-C-9002 to Universal Construction Company, Decatur, Alabama. Worth $1,923,400 in original award value, the project was due for completion in February 1977.[22]

The Universal Construction contract for the Space Shuttle Mated Ground Vibration Test Facility was the last piece of Shuttle-related activity performed by the Huntsville Division in conjunction with NASA at the MSFC. During the course of Shuttle construction, however, NASA had developed a working relationship with the Division strengthened by three projects that were not associated with the Shuttle. Though relatively small in dollar value, each of these miscellaneous NASA projects had several points worthy of mention in this **History.**

The first MSFC non-Shuttle project was also the smallest. Following the award of contracts for the Acoustic Model Engine Test Facility and the Electrical Laboratory Addition in February 1973, NASA asked for and received Corps assistance in revising the climatic control system for Bldg. 4487. System design was retained by NASA, but Huntsville Division awarded the $183,287 construction contract to Quinn Construction Company of Huntsville on 29 May 1974. The major part of this job consisted of removal and replacement of the system's sixty-ton chiller unit and associated service lines.[23]

Huntsville Division's second non-Shuttle task at the MSFC was born out of a violent act of Mother Nature. In early April 1974 a tornado struck Bldg. 4200, a modern glass-and enamel panel ten-story office structure housing the headquarters of the MSFC. In the flick of an eye, the storm twisted the building a few centimeters and released it, passing on to inflict severe damage and several deaths in the Huntsville area. In the aftermath of the storm, inspection revealed dozens of broken windows, warped window frames, twisted mullions and gutters, and several four-foot by four-foot procelain enamel inserts stripped from the building's exterior curtain wall. What lay beyond this in the internal steel framing no one knew for sure, since a precise assessment would have necessitated either pulling off most of the damaged external curtain wall or removing many hundred feet of complicated heating ducts along the interior floor baseboards. Neither was a very palatable or practical alternative. In the ensuing weeks, NASA architects evaluated the damage as best they could, and the Agency advertised for repairs. Bidding response was poor, however, probably because potential contractors were put off by a somewhat ambiguous work description and fears that a contract might bind them to repair as yet undiscovered damages beyond the curtain wall exterior. The one bid of $550,000 received was judged unacceptably high, and constrained by fiscal year budgetary allocations, NASA solicited Huntsville Division for advice.

Division engineers examined the building, assessed the curtain wall damage, and determined that internal structural framing damage was probably minimal. The Division then organized a unit price schedule through which a contractor could bid on twenty-four specific categories of repair items and operations--replacing a window frame, for example, or repairing a mullion. To further reassure potential bidders, an all-day prebid conference complete with a walk-through damage inspection tour led by Huntsville Division's William Major was held at Bldg. 4200. These procedures produced five bids, among which was a low bid of $274,728.30 offered by K & M Paint & Glass of Huntsville. K & M's low bid was accepted by NASA, and a Corps contract was awarded on 10 October 1974. Even though the original contract value was raised some $10,000 by two subsequent modifications, the Division achieved a savings of some $265,000 for the Space Agency.[24]

The third non-Shuttle project carried out by Huntsville Division for NASA reflected the Agency's diversification beyond space exploration and the increasing national interest in new energy sources beyond petroleum. To encourage investigation of alternative energy sources, in 1974 the Congress passed the "Solar Heating and Cooling Demonstration Act." It was signed into law by President Ford on 3 September 1974. The Act called for a $60 million, five-year program for technology research and development on solar heating and cooling for buildings. The research, development, and demonstration were to be handled by NASA, since the Space Agency had considerable experience with the unique scientific knowledge and specialized technology to exploit the sun's radiation. In constructing their "Solar Heating and Cooling Breadboard Test Facility," however, NASA believed that the Huntsville Division could offer assistance in design and construction of the facility of the tight time

schedule that the Agency faced.

NASA's design criteria were specified in November 1975, and because of the pressing need date, the engineering design was performed in-house by the staff of the Engineering Division rather than contracted through an AE firm. The resulting design provided the capability to test either air or liquid (water, water-ethylene glycol) solar heating and cooling systems and subsystems with total solar collection, or with total or partial simulation of solar collection. Two active solar panel areas could collect and supply solar energy; one passive panel without fluid connections served to evaluate the effects of thermal stagnation and the effects of the weather. All three structures were simple wooden truss frameworks supporting solar collection panels. Test bed facilities nearby housing complexes of pumps, heat exchangers, fans, cooling coils, a cooling tower, electric hot water boilers, and centrifugal chillers to permit concurrent testing of solar energy equipment. Instrumentation was to be provided by NASA. Structurally, the "thermal breadboards" required remodelling one existing utility building and the relocation of two others on new slabs.

A contract for the above construction was awarded to Ivey's Plumbing and Electrical Company, Inc., of Kosciusko, Mississippi, on 17 March 1976. Ivey's low bid of $647,243 compared favorably with Government estimates of $644,068. Originally due for completion on 1 November 1976, ten sizeable modifications worth $66,190.27 delayed acceptance of the project until 22 April 1977.[25]

*"Solar Heating and Cooling Breadboard Test Facility" designed in-house by Huntsvillians and constructed under contract at Marshall Test Facility.*

# CHAPTER V FOOTNOTES

### I. The Bulk Mail Centers Procurement for the U.S. Postal Service

[1]Typescript report by Dennis S. Lavery, PhD, for the Corps of Engineers, "The Postal Support Effort in the Corps of Engineers," 17 February 1976, pp. ii -3. Henceforth cited as Lavery, "Postal Report for CE."

[2]This is the opinion presented in Lavery, "Postal Report for CE," pp. 4-5, and that of personnel involved in the Postal mission at USAEDH.

[3]Lavery, "Postal Report for CE," pp. 4-5.

[4]Ibid.,pp. 5-9.

[5]Memo of Howard H. Callaway, Sec. of Army, for Sec of Def, 6 Jun 74, concerning assumption of ERDA coal gasification work by Corps of Engineers. USAEDH ERDA Liaison Office file, Memoranda of Agreements.

[6]"Memorandum of Working Agreement Between the Post Office Department and the Corps of Engineers, Department of the Army Providing for the Assignment of USPOD Facilities Program Functions to the Corps of Engineers," signed by Maj. Gen. D.A. Raymond, Director of Military Construction, OCE, and by L.P. Gyh, Assistant Postmaster General, Post Office Department, on 20 May 1971,USAEDH Procurement and Supply Division file, Postal Procurement.

[7]"Memorandum of Agreement Between the Post Office Department and the Department of the Army Providing for Postal Facilities Acquisition Services," signed by Stanley R. Resor, Sec of the Army, and Winton M. Blount, Postmaster General, on 11 March 1971; Lavery, "Postal Report for CE," pp. 9-11.

[8]Lavery, "Postal Report for CE," passim.

[9]Ibid., pp. 65-66.

[10]Ibid., p. 66.

[11]Ibid., pp. 66-67; personal interviews with Roy E. Edwards, Chief, Postal Field Support Branch, USAEDH-PS, March 1977 and April 1978.

[12]Lavery, "Postal Report to CE," p. 67.

[13]Ltr, OCE to Division Engineer USAEDH, 26 Nov 71, sub: Procurement of Fixed Mechanization Components for the Postal Service Bulk Mail System. USAEDH Procurement and Supply Division file, Postal Support Mission.

[14]Ibid.

[15]Personal interviews with Roy E. Edwards, Chief, Postal Field Support Branch, USAEDH-PS, March 1977 and April 1978.

[16]Ltr, OCE to Div Engr USAEDH, 26 Nov 71, sub: Procurement of Fixed Mechanization Components for Postal Service Bulk Mail System. USAEDH-PS, Postal Support Mission File.

[17]USAEDH-PAO, "Information Bulletin," IV, No. 17 (15 Oct. 1971), p. 3.

[18]"Memorandum of Agreement Between the SAFEGUARD System Organization and the U.S. Army Corps of Engineers Providing for Use of the Huntsville Engineer Division in the Procurement of Fixed Mechanization Equipment for the Postal Service Bulk Mail System," signed by Lt. Gen. F.J. Clarke, Chf of Engrs, and Lt Gen W.P. Leber, SAFEGUARD System Manager, on 22 Nov 71. USADEH-PS, Postal Support Mission File. This document is also reproduced in USAEDH-PAO, "Historical Summary FY 1972," II, Documents, p. 74.

[19]Ibid.

[20]See, for example, ER 10-1-22 editions of 28 July 1972 and 20 January 1975.

[21]USADEH-PAO, "Historical Summary FY 1972," II, Documents, p. 73.

[22]Lavery, "Postal Report for CE," p. 68; USAEDH—PAO, "Information Bulletin," V, No. 9 (22 Sept. 1972), p. 1.

[23]Personal interviews with Roy E. Edwards, Chief, Postal Field Support Branch, USAEDH-PS, March 1977 and April 1978, and with Thor S. Anderson, Chief, Procurement and Supply Division, USAEDH, May 1978.

[24]Personal interviews with Roy E. Edwards, Chief, Postal Field Support Branch, UASEDH-PS, April 1978. The text of ER 1180-6-1, "Government Furnished Property for Postal Bulk Mail Centers," 4 June 1973, is entirely reproduced in USAEDH-PAO, "Government Furnished Property (GFP) After Action Report: Bulk Mail Postal Procurement Program, USPS Modernization Improvement Program," April 1977.

[25]USAEDH-PAO, "Government Furnished Property (GFP) After Action Report: Bulk Mail Postal Procurement Program, USPS Modernization Improvement Program," April 1977, p. 7. Henceforth cited as USAEDH-PAO, "Postal GFP After Action Report."

[26]USAEDH-PAO, "Information Bulletin," V, No. 9 (22 Sept. 1972), p.1.

[27]Personal interviews with Roy E. Edwards, Chief, Postal Field Support Branch, USAEDH-PS, March 1977 and April 1978; USAEDH-PAO, "Postal GFP After Action Report," passim; Lavery, "Postal Report for CE," pp. 70-71.

[28]Personal interviews with Roy E. Edwards, Chief, Postal Field Support Branch, USAEDH-PS, March 1977 and April 1978; USAEDH-PAO, "Postal GFP After Action Report," pp. 6-7.

[29]USAEDH-PAO, "Postal GFP After Action Report," pp. 8-11; Lavery, "Postal Report for CE," pp. 76-77.

[30]The concept of "subscription mailing" was extensively discussed through several interviews with Roy E. Edwards during the spring of 1978. His comments were supplemented by careful review and further information supplied by James Reynolds, Contract Specialist of the Procurement and Supply Division. The descriptions in Lavery, "Postal Report for CE," pp. 73-75 are highly generalized and somewhat misleading.

[31]Personal interview with Roy E. Edwards, April 1978.

[32]The figure of $441,816.00 is supplied by Lavery, "Postal Report for CE," p. 75.

[33]Personal interview with Roy E. Edwards, April 1978.

[34]Personal interview with Roy E. Edwards, April 1978; Lavery, "Postal Report for CE," pp. 74-75.

[35]Personal interview with Roy E. Edwards, April 1978.

[36]USAEDH-PS raw input data for "Historical Summary FY 1976," USAEDH—PAO Historical Summary file.

[37]Memo to the author from Thor S. Anderson, July 1978.

[38]Report, U.S. General Accounting Office (Atlanta Regional Office), February 1974, "Summary on Survey of the Mechanization Acquisition for the National Bulk Mail System (Code 22269)," pp. 16-17.

### II. The NASA Space Shuttle Mission and Other NASA Projects

[1]NASA, "National Aeronautics and Space Administration. Space Shuttle Fact Sheet," October 1972, pp. 2-3.

[2]Ibid., p. 4.

[3]Ibid., p. 5.

[4]Formerly called the Mississippi Test Facility (MTF).

[5]"Memorandum of Agreement Between the SAFEGUARD System Organization and the US Army Corps of Engineers Providing for USE of the Huntsville Division for other than SAFEGUARD Projects," signed by Lt. Gen. F.J. Clarke, Chief of Engineers, and Lt. Gen. W.P. Leber, SAFEGUARD System Manager, on 8 Jun 72. NASA Memorandum of Agreement file, USAEDH-ED. This "Memorandum of Agreement" is not reproduced in the "Historical Summary FY 1972."

[6]USAEDH-PAO, "Historical Summary FY 1972," I, Narrative, pp. 1-5; USAEDH-PAO, "Historical Summary FY 1973," I, Narrative, pp. 1-8.

[7]See Division organization charts in the "Historical Summary" for FY 1972 and 1973.

[8]Personal interviews with William Major, Project Management Branch, USAEDH-ED, March 1977 and May 1978; Miscellaneous "Project Descriptions." USAEDH-ED, NASA Project Descriptions File.

[9]Miscellaneous "Project Descriptions," USAEDH-ED, NASA Project Descriptions File.

[10]Contract Record File, AE Contract Records Section, USAEDH-ED.

[11]Miscellaneous "Project Descriptions," USAEDH -ED, NASA Project Descriptions File.

[12]Miscellaneous "Project Descriptions," USAEDH-ED, NASA Project Descriptions File.

[13]Miscellaneous "Project Descriptions," USAEDH-ED, NASA Project Descriptions File; NASA, "NASA Shuttle Construction Projects Data Book," 30 April 1976, pp. 51-52.

[14]NASA, "NASA Shuttle Construction Projects Data Book," 30 April 1976, pp. 51-52; Miscellaneous "Project Descriptions," USAEDH -ED, NASA Project Descriptions File; Personal interviews with William Major, Project Management Branch, USAEDH-ED, March 1977 and May 1978.

[15]NASA, "NASA Shuttle Construction Projects Data Book," 30 April 1976, pp. 51-52; Miscellaneous "Project Descriptions," USAEDH-ED, NASA Project Descriptions File; Personal interviews with William Major, Project Management Branch, USAEDH-ED, March 1977 and May 1978.

[16]Frank D. Lewis and George G. Stewart, "The Corps and the Space Shuttle Program," **The Engineer,** VI, No. 3 (July-Aug.-Sept. 1976), pp. 28-31; Craig Covault, "Shuttle Engine Delays Overcome," **Aviation Week and Space Technology,** CV, No. 1 (5 July 1976), pp. 43-49.

[17]NASA, "NASA Shuttle Construction Projects Data Book," 30 April 1976, pp. 3, 25; USAEDH-PAO, "Historical Summary FY 1973," II, Documents, p. 109; NASA program scheduling data sheets dated 11 Apr 75 retained by William Major, Project Management Branch, USAEDH-ED.

[18]USAEDH-PAO, "Historical Summary FY 1973," II, Documents, p. 98; NASA program scheduling data sheets dated 11 Apr 75 retained by William Major, Project Management Branch, USAEDH-ED.

[19]USAEDH-PAO, "Historical Summary FY 1973," II, Documents, p. 100; Miscellaneous NASA program scheduling data sheets retained by William Major, Project Management Branch, USAEDH-ED; Personal interviews with William Major, Project Management Branch, USAEDH-ED, March 1977 and May 1978.

[20]NASA, "NASA Shuttle Construction Projects Data Book," 30 April 1976, pp. 11-13; Miscellaneous NASA program scheduling data sheets dated 11 Apr 75 retained by William Major, Project Management Branch, USAEDH-ED; USAEDH-PAO, "Historical Summary FY 1975," II, Documents, p. 99.

[21]USAEDH-PAO, "Historical Summary FY 1975," II, Documents, p. 102; USAEDH-PS raw input data for "Historical Summary FY 1976," USAEDH-PAO "Historical Summary FY 1976" raw input data file.

[22]NASA, "NASA Shuttle Construction Projects Data Book," 30 April 1976, pp. 15-16; USAEDH-PS raw input data for "Historical Summary FY 1976," USAEDH-PAO "Historical Summary FY 1976" file.

[23]USAEDH-PAO "Historical Summary FY 1974," II, Documents, p. 122.

[24]Personal interviews with William Major, Project Management Branch, USAEDH-ED, March 1977 and May 1978; USAEDH-PAO, "Historical Summary FY 1975," II, Documents, p. 97.

[25]Personal interview with Clyde C. Wright, Mechanical-Electrical Branch, USAEDH -ED, May 1978; USAEDH-PS raw input data for "Historical Summary FY 1976," USAEDH-PAO "Historical Summary FY 1976" file.