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An Investigation into the Disposal of Low Level Radioactive Waste in Outer Space

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A Reaserch Paper for Presentation
to the Graduate Faculty
of the
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In Partial Fulfillment of the Requirements for
the Non-Thesis Master of Arts Degree

By
Michael S. Cook
Summer, 1992

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AN INVESTIGATION INTO THE DISPOSAL OF LOW LEVEL RADIOACTIVE WASTE IN OUTER SPACE

A Research Paper

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CHAPTER I

INTRODUCTION

Problem Statement

This research involved studying the feasibility of removal of low level radioactive waste (LLRW) from earth to outer space as a long term safe alternative to current methods. The primary focus was concerned about LLRW commonly found in landfills.

Statement of Purpose

The purpose of this study was to investigate use of space technology and other technological breakthroughs to solve a waste disposal problem.

Effective disposal of LLRW on the planet earth is a serious concern. Man is currently depleting his waste storage space and longevity on earth by burying large quantities of hazardous waste in landfills. This will eventually allow waste to reappear as pollutants in our biosphere. Disposing of these hazardous materials on earth often spreads the pollutants thus, intensifying the problem. Hazardous waste continues to inflict non-repairable damage to natural resources and inhabitants. A thorough look at disposal of LLRW in outer space will benefit development of a long term solution.

Statement of Need

This study was based on a need for the long range salvation of our environment for future generations. Salvation of our environment depends on our ability to dispose of LLRW effectively. This research will involve studying the feasibility for disposal of low level radioactive waste in outer space.

The U.S. government in late 1989 admitted that it would have to revamp and delay its plans to build a radioactive waste dump site. Environmental problems at the planned Carlsbad New-Mexico site were the primary reason for revamping. LLRW has raised a new set of questions about the need for nuclear power (Saleska, 1990). The Nuclear Regulatory Commission (NRC) and congress are trying to deregulate nuclear waste and place LLRW in landfills, incinerators, sewage systems, recycling centers and sludge for deposit on farmland. Some of this LLRW could find its way into consumer products such as kitchen appliances and children's toys (Wasserman, 1990). Since 1960 the federal government has spent $1 billion dollars in search of a site. This site must be environmentally and politically safe to bury high level radioactive waste (HLRW) and LLRW from nuclear reactors (Time, 1987).

Since 1979, existing dump sites have closed due to long term negative effects on the environment. Some medical and research facilities lacked adequate LLRW storage space. These facilities were within two weeks of shutting down. (Norman, 1985). A solution to the LLRW disposal issue is necessary. If no solution is found, the effects will be felt in all aspects of medical care (Adelstein, & McKusick, 1986).

Federal scientist are focusing their scrutiny and more than $1 billion on Nevada's Yucca Mountain, as the probable site of the nation's first HLRW dump. There is no doubt that the repository will leak over the course of the next 10,000 years. The concern of the NRC is deciding whether the repository can sufficiently limit the radioactivity that reaches the environment (Manastarky, 1988). In reviewing these problems and the money expended so far, no clear solution is apparent. These facts make disposal of this material in outer space appear more attractive.

Research Questions

Below is a list of questions answered by this study concerning the disposal of LLRW in outer space.

1. Will LLRW disposal in outer space have any adverse effects or repercussions on earth?
2. Will there be any financial benefits associated with the disposal of LLRW in outer space versus current methods?

3. What is the approximate cost of current methods versus methodologies proposed for outer space? These estimates should include long term ramifications associated with loss of life and natural resources.

4. What kind of processing is required before transport, to ensure safety during transport into outer space?

Assumptions

The following assumptions were made in pursuit of this study:

1. A low cost expendable space vehicle could transport LLRW into earths orbit. Upon reaching earth's orbit a space shuttle could rendezvous with expendable space vehicle and guide it to a storage site for a soft landing on the lunar surface.

2. To prepare this material for transport into outer space a processing system is necessary. This processing plant would have the responsibility of preparing LLRW for transport by performing the following tasks:

   a. LLRW must be packaged into containers that can withstand high impact from explosions and high heat if a mishap occurs with the projectiles.

   b. The impact proof containers would have parachutes attached that would open upon sensing a free fall. This will allow a soft landing and reduce the adverse effects of a sudden impact.

c. It is obvious that a method for handling waste disposal has involved getting the waste out of sight. As a result, waste shows up later as a pollutant. That is why the proposed method of removing waste from the earth to outer space is an attractive alternative for saving our environment.

Limitations

At the time of the study, no cost figures were available concerning damage due to inadequate waste disposal methods. With increasing quantities of LLRW, limitations in this area of disposal existed. This study was limited to studying the feasibility of transporting LLRW into outer space. Further limitations existed relative to the geographical location of the researcher.

Delimitations

This study was conducted in view of the following delimitations:

1. The scope of this project was delimited to providing answers for research questions through literature search and interviews.
2. Because of the variety of waste, this study focused on LLRW. Figure (1) on the following page shows sources of LLRW. It will also identify the industries contributing to this problem.

Sources of Low Level Radioactive Waste

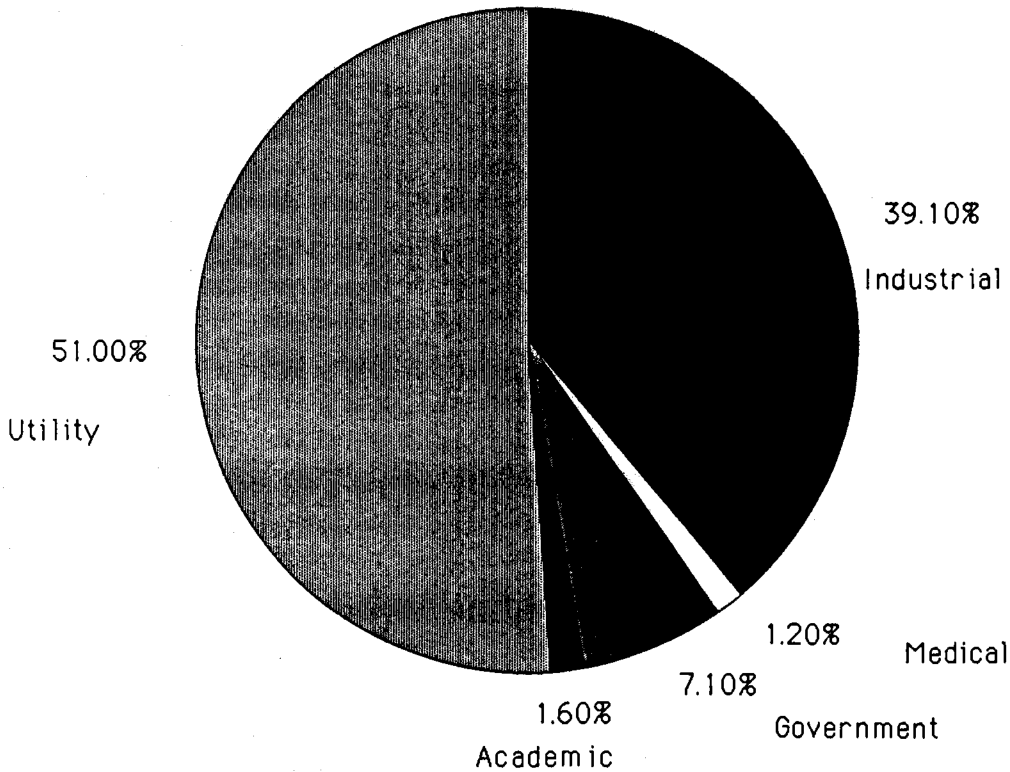


Figure 1

Figure 1 is from the information gathered by the EG and C Idaho INC., for the U.S. Department of Energy, By P. Furigda,(1989).

Definition of Terms

The following terms are defined to clarify their use in the study.

- Low Level Radioactive Waste (LLRW). Radioactive clothing and equipment from power plants, industry, medical applications and research (Saleska, 1990). Half lives of low level radioactive waste is approximately 10-20 years.
- High Level Radioactive Waste (HLRW) Intensively Radioactive material that requires heavy shielding to protect those who handle it against penetrating radiation and intense heat. Half lives of HLRW is approximately 5,000 - 10,000 years.
- Expendable Launch Vehicles (ELV) are unmanned space craft that carry payloads to a predetermined destination.
- Space Transportation System (STS) are responsible for the design and management of space flight planning and prelaunch preparations. A handbook outlining the procedure for preparing space cargos is available.

CHAPTER II

REVIEW OF LITERATURE

The primary purpose of this literature review was to examine the studies relating to disposal of hazardous waste in outer space. To accomplish this a library search was conducted using the following topics.

1. Hazardous waste in outer space
2. Disposal of hazardous waste in outer space

3. Disposal of radioactive waste in outer space

4. Outer space waste

Time was spent researching the different types of space vehicles. Information was gathered to verify the feasibility of vehicles based upon theoretical selection criteria.

Transport vehicle	Reliability	Safety	Cost Rating	New Technology	Range of vehicle	Total score
Space Shuttle	6	7	7	8	4	32
Expendable Launch vehicle	9	9	8	5	5	36
Rail Accelerator	7	8	9	7	9	40

(Figure 2)
Figure 2 above is from the researchers estimated or assumed criteria.
The criteria has been weighted to aid in evaluating space transport vehicles. The above items are rated on a scale of 1-10 1 is the lowest value and 10 is the highest.

Figure 2 above summarizes the results and considerations used to determine the most feasible vehicle.

Space Transportation System (STS)

STS customers must develop payloads based on the STS hand books and customer guidelines (McDonnel Douglas, 1987). Forms to complement the activities for processing payloads for transport are available. (See Appendix D)

Space Vehicle Research

Three types of vehicles have been researched; expendable launch vehicles ELVs, rail accelerators and the space shuttle. The first two vehicles are unmanned and have ranges that exceed low earth orbit. The expendable launch vehicles observed on the field trip are unmanned space craft capable of carrying large commercial payloads to predetermined destinations (Wybranowski, 1991). Destination and payload capacities are dependent upon vehicle type selection (Pontowski, 1988). Figure 3 depicts the various expendable launch vehicle types available. Load carrying capacity, dimensions and cost for launch services are shown (LeBarge, 1991). Figures 4, 5,and 6 show dimensional and orbital characteristics.

U. S. EXPENDABLE LAUNCH VEHICLES

VEHICLE	AVALABILITY	PERFORMANCE (i = 28 DEG.) LBS. LEO	GTO	GSO	(i = 90) POLAR	PAYLOAD FAIRING DIA. (FT.)	ESTIMATED VEHICLE LAUNCH SERVICES COSTS 1990 ($)
PEGASUS	NOW	1100	275		840	4.2	10 - 15M
SCOUT-WFF/WTR	NOW	570 (WFF)			460 (WTR)	2.9 & 3.5	10 - 20M
DELTA II MODEL 6920/6925 MODEL 7920/7925	THRU 1992 NOW	8780 (6920) 11110 (7920) 10830 (7920)	3190 (6925) 4010 (7925) 3900 (7925)	1600 (6925) 2000 (7925) 1890 (7925)	6490 (6920) 8420 (7920) 8150 (7920)	8 & 9.5 9.5 10	40 - 50M
ATLAS I	THRU 1993/94	12400 11950	5150 4950			11 14	65 - 70M
ATLAS II*	1991	14350 13950	6100 5900			11 14	70 - 80M
ATLAS IIA	1992	15700 15250	6400 6200			11 14	80 - 90M
ATLAS IIAS	1993	18400 17900	8000 7700			11 14	110 - 120M
TITAN II*	NOW				4200	10	35 - 40M
TITAN III WITH SRMU	NOW LATE 1992	30500 38000	11000			13.1	145 -155M
TITAN III / TOS	1992		13000			13.1	140 - 200M
TITAN III / IUS WITH SRMU	LATE 1992			4200 5000		10	245 - 255M
TITAN IV* / NUS WIYH SRMU	NOW LATE 1992	39000 49000			31200 41400	16.7	180 - 240M
TITAN IV* / IUS WITH SRMU	NOW LATE 1992	49000	15000	5200	6600	16.7	280 - 340M
TITAN IV * /CENTAUR WITH SRMU	NOW LATE 1992			10200 13500**		16.7	260 - 320M

FIG. (3)

* NOT COMMERCIALLY AVAILABLE

** CURRENT CENTAUR IS STRUCTURALLY LIMITED TO 11500 LBS.

FIGURE (3) Depicts the various ELV types, availability load carrying capacity, size and cost of launch services. [Information furnished by B. Lebarge Lewis Research Center.]

Delta Rocket Envelope Configuration

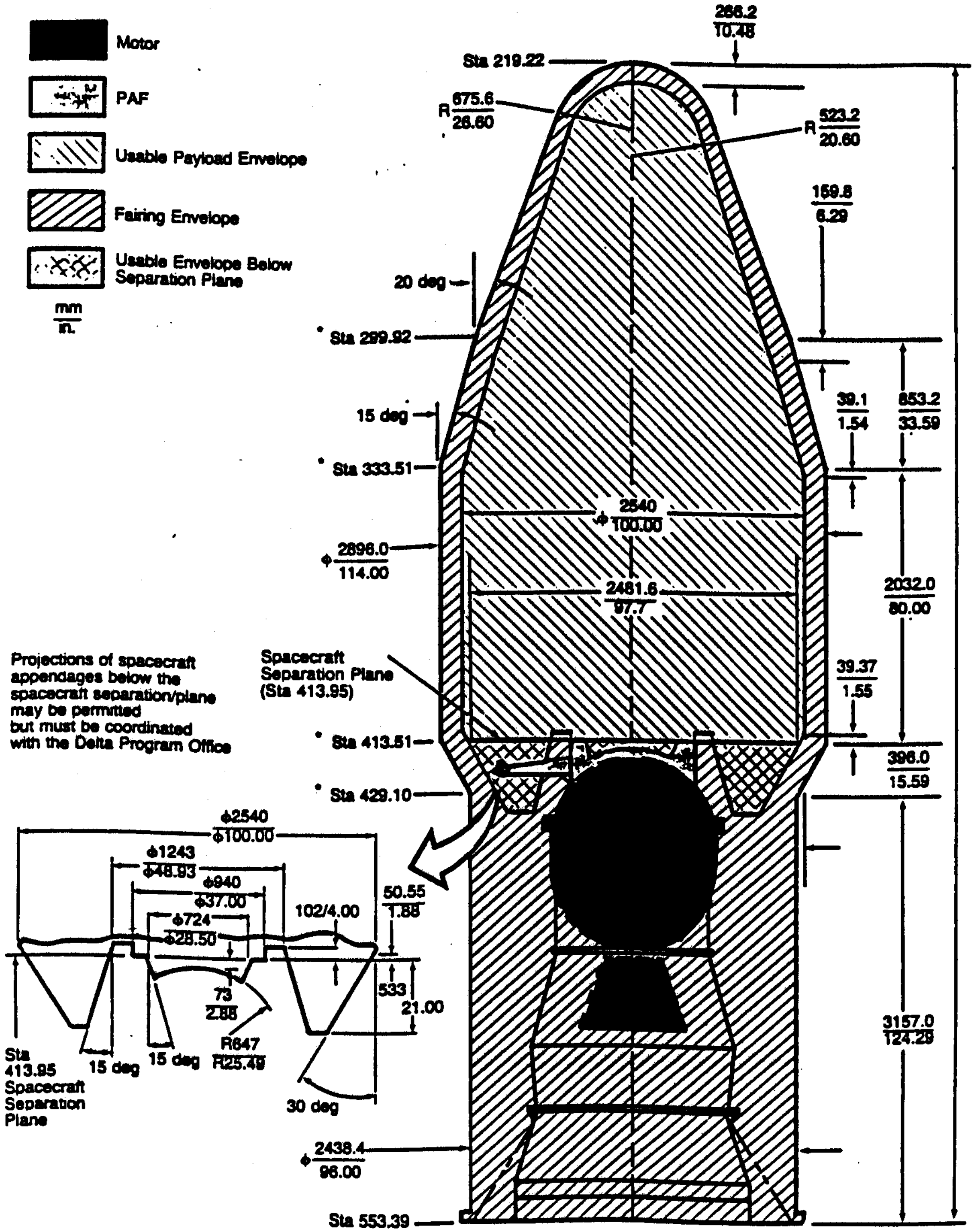


Figure 4

Figure 4: The figure above shows the Delta Rocket Space Craft Envelope Configuration.
Source: From Mcdonnell Douglas, (1990).

Delta Rocket Configuration

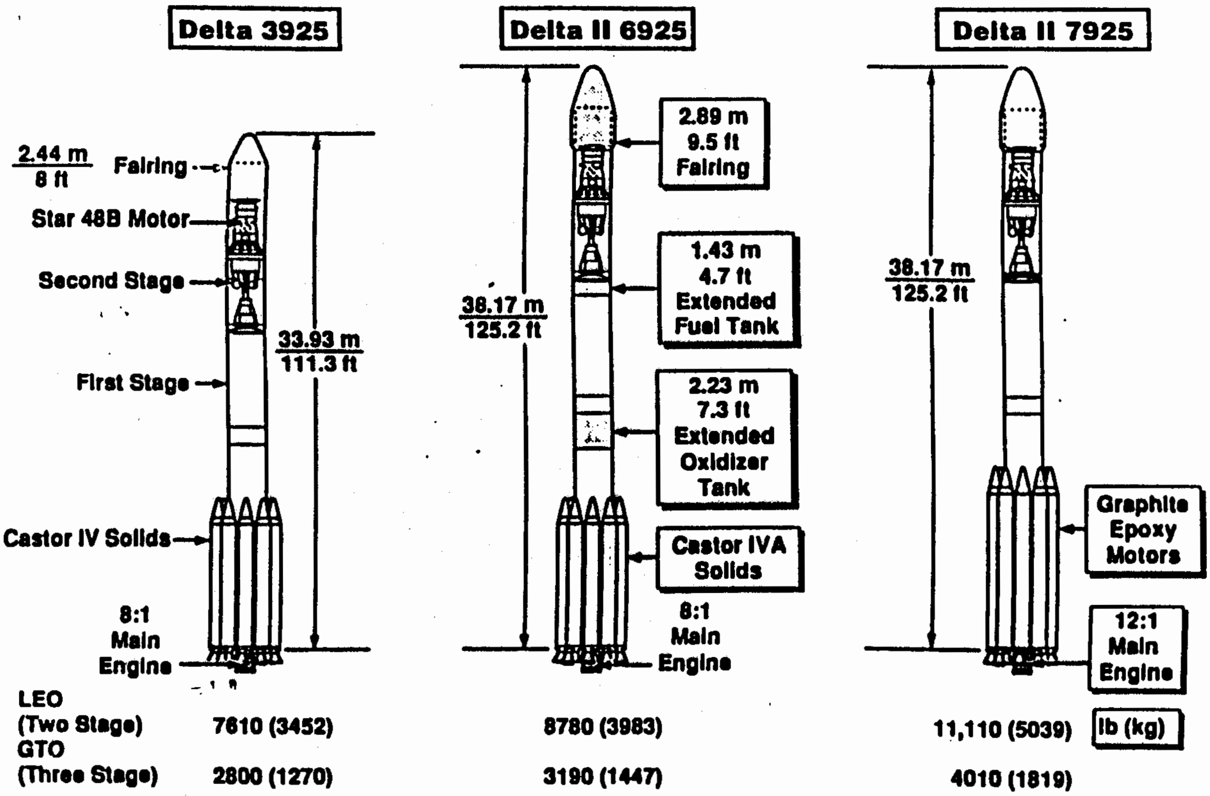


Figure 5

Figure 5: The Figure above shows the Delta Rocket Configuration.
Source: From McDonnell Douglas, (1990).

Delta Rocket Booster Profile

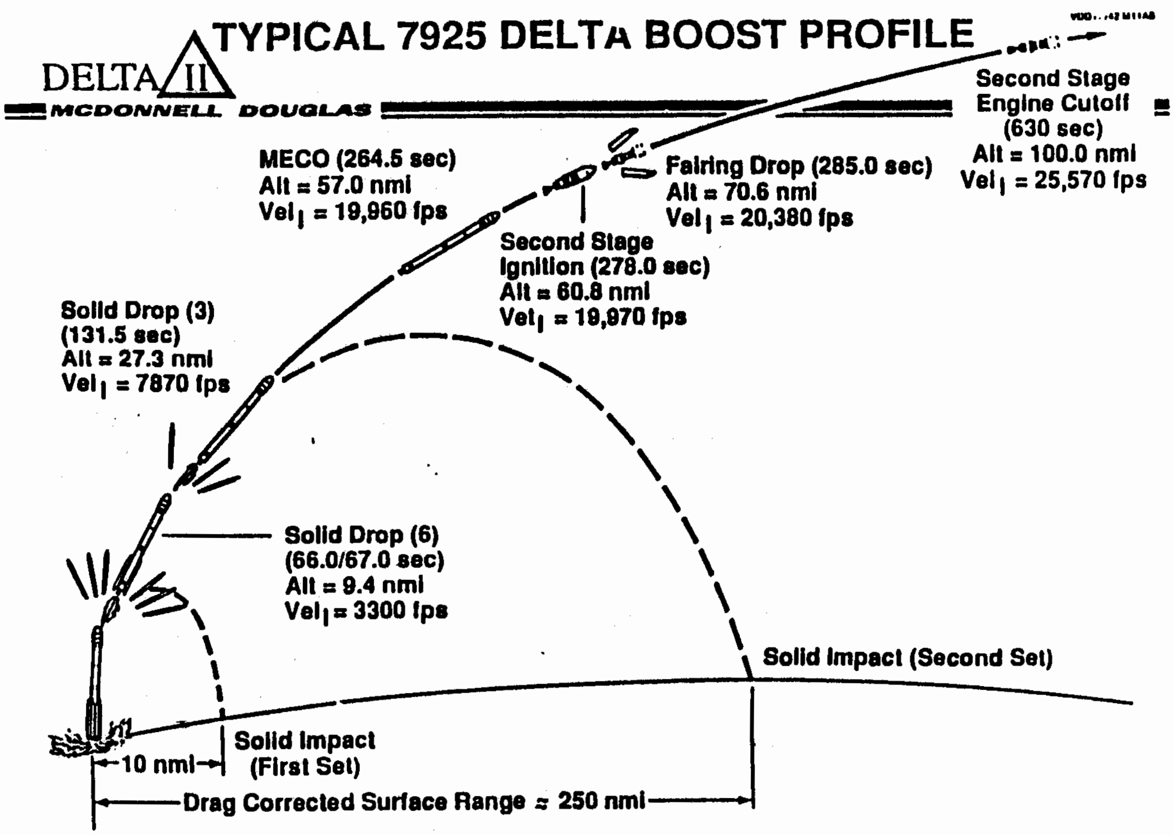
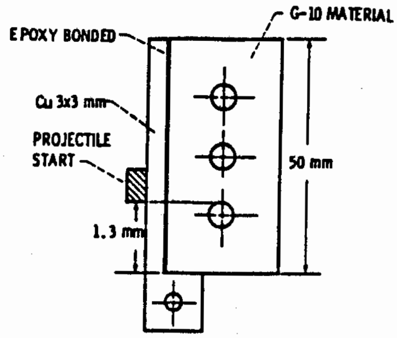


Figure 6

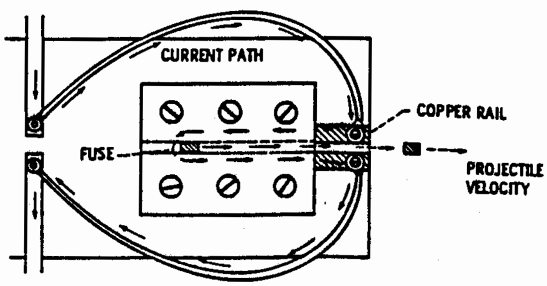
Figure 6: The figure above shows the Delta Rocket Booster Profile.
Source: McDonnel Douglas, (1990).

Another type of unmanned space vehicle is the rail accelerator. This technology uses electromagnetic propulsion for transport. This idea has been in existence since the early 1900's (Kerslake, & Cybyk, 1982). This is the same technology used by Sadam Husein to develop a super canon during the Persian gulf war. The rail accelerator produces a sling shot effect on projectiles to initiate propulsion (Kerslake, & Cybyk, 1982). The Lewis Research Center has studied the feasibility of sending ton size payloads of radioactive waste into deep space. It was looked at for launching space cargos and consumables into deep space. Cost estimates from 1981 were between 5 to 8 billion dollars to build a rail accelerator launch facility. The rail accelerator, in the long term, would be 30 to 50 times less expensive than the space shuttle launch costs. The study design would have required 600,000 kilo-joules at a current of 28,000 kilo-amps to handle ton size payloads (Krysiak, 1991). Figures 7-9 on pages 14-16 will illustrate the launcher concept.

Rail Accelerator Test Design



Thin rail accelerator design (left rail not shown).



Reverse current test of rail accelerator.

Figure 7

Figure 7 is taken from LeRC Rail Accelerators: Test Design and Diagnostic Techniques, L.M. Zana, W.R. Kerslake, J.C. Sturman, S.Y. Wang and F.F. Terdan, Lewis Research Center, (1983).

Projectile Design for Nuclear Waste Disposal

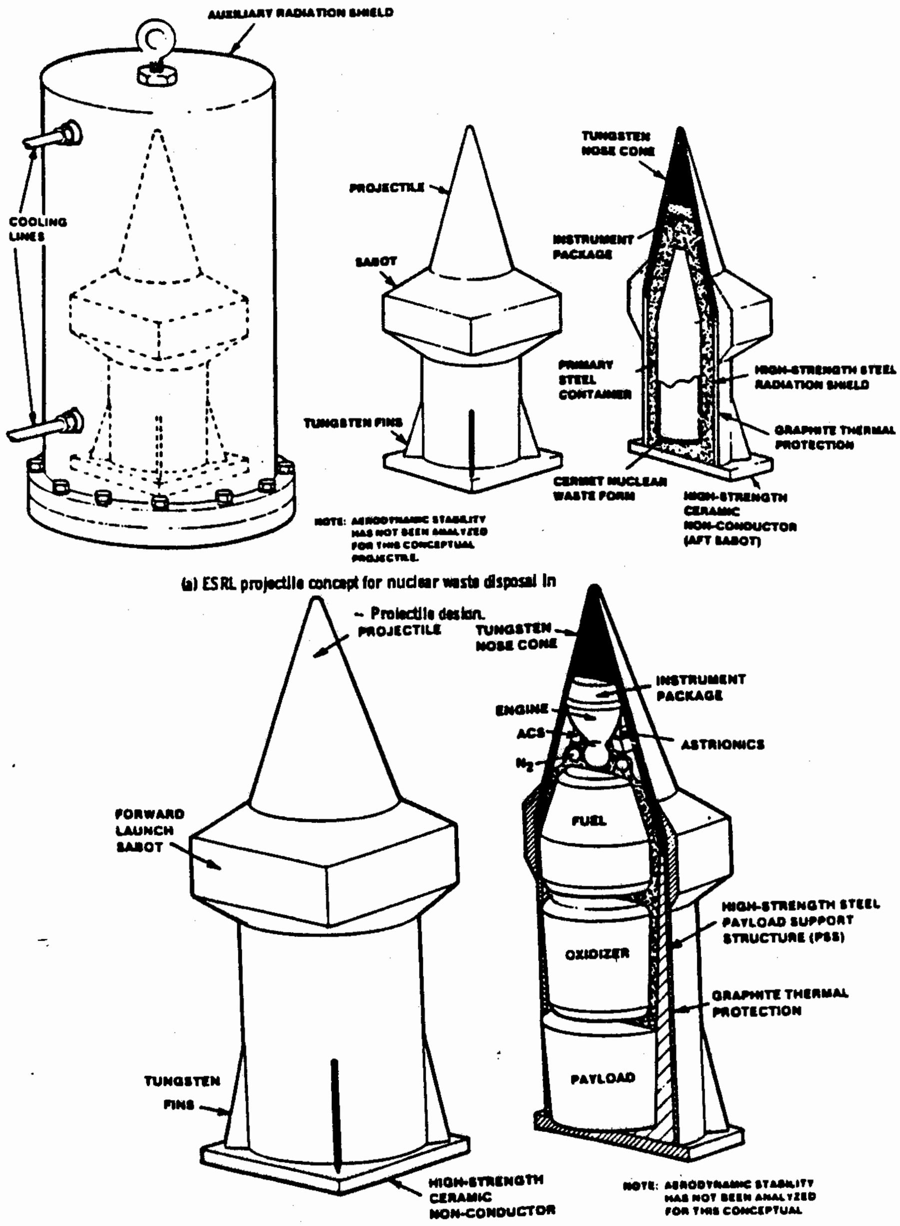
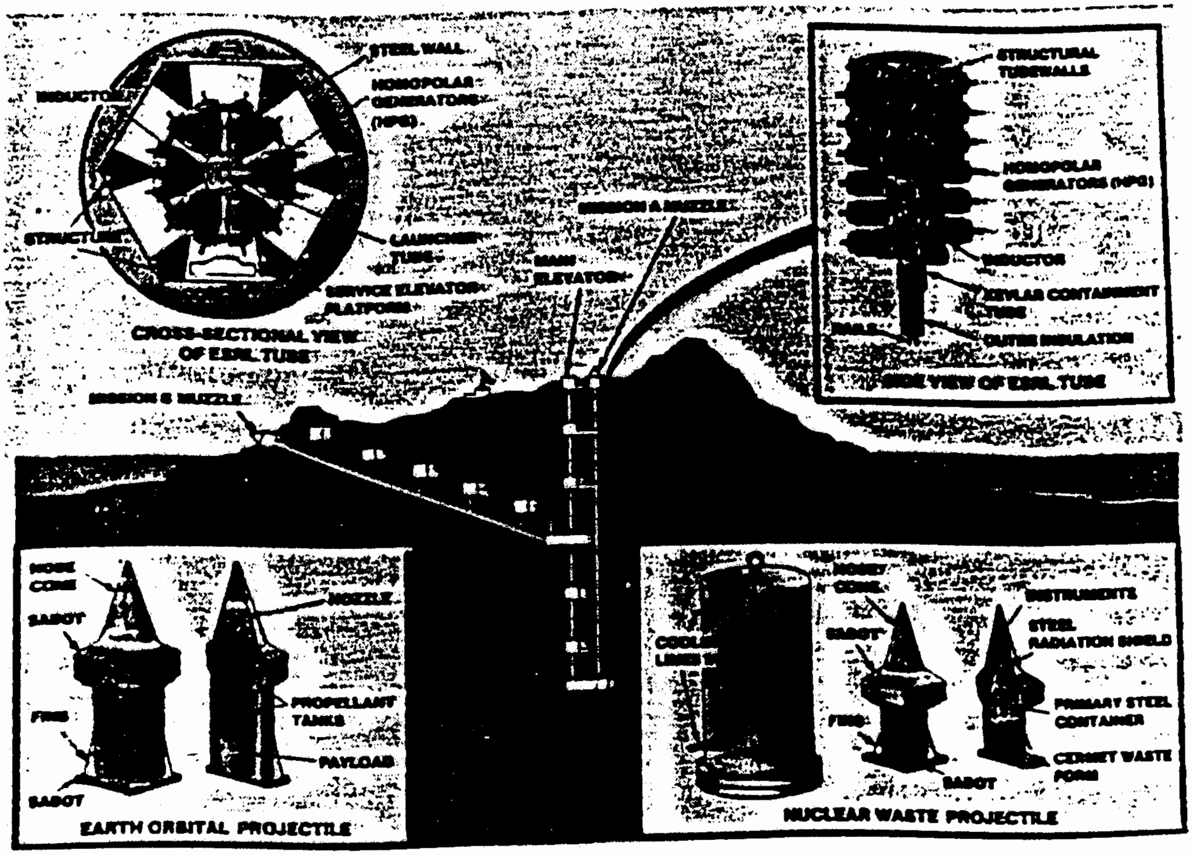


Figure 8

Figure 8 is taken from LeRC Rail Accelerators: Test Design and Diagnostic Techniques, L.M. Zana, W.R. Kerslake, J.C. Sturman, S.Y. Wang and F.F. Terdan, Lewis Research Center, (1983).

Rail Launcher Facility



Side view of rail launcher facility, each launcher tube is 2km long.

Figure 9

Figure 9 is taken from LeRC Rail Accelerators: Test Design and Diagnostic Techniques, L.M. Zana, W.R. Kerslake, J.C. Sturman, S.Y. Wang and F.F. Terdan, Lewis Research Center, (1983).

The final vehicle to study is the space shuttle and related technology. This vehicle is a staffed space craft used for deployment of satellites. The space shuttle is designated for space station deployment and support (NASA, 1981). The following figures depict the configurations of the Space shuttle.

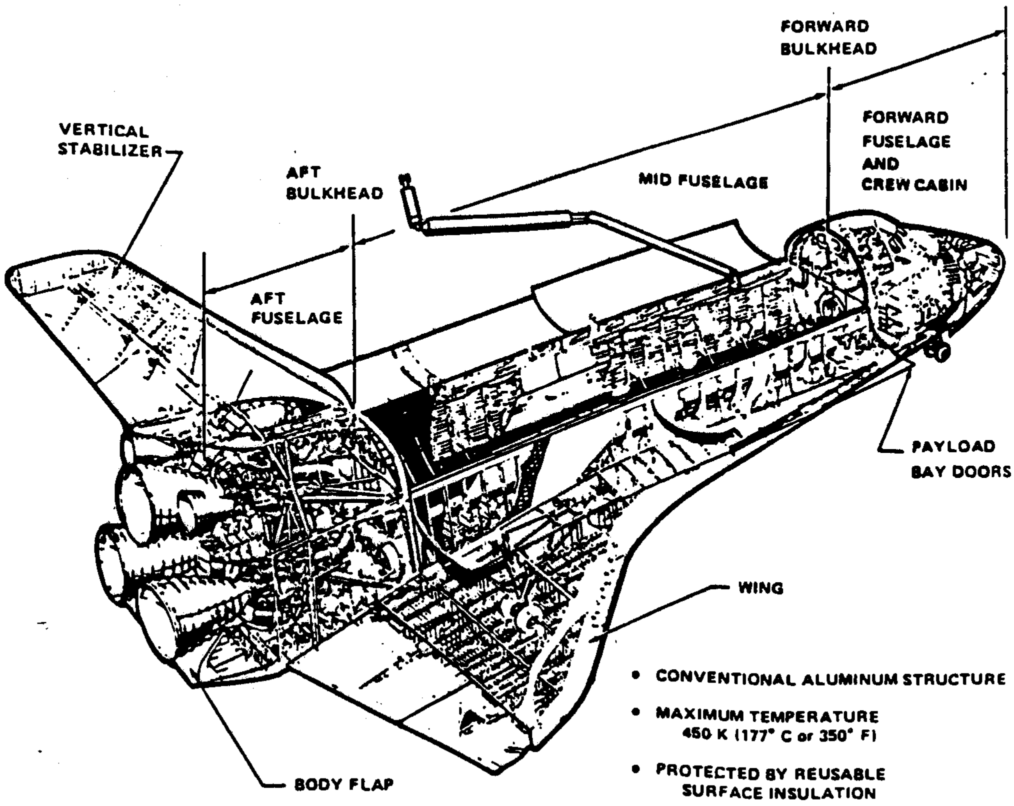
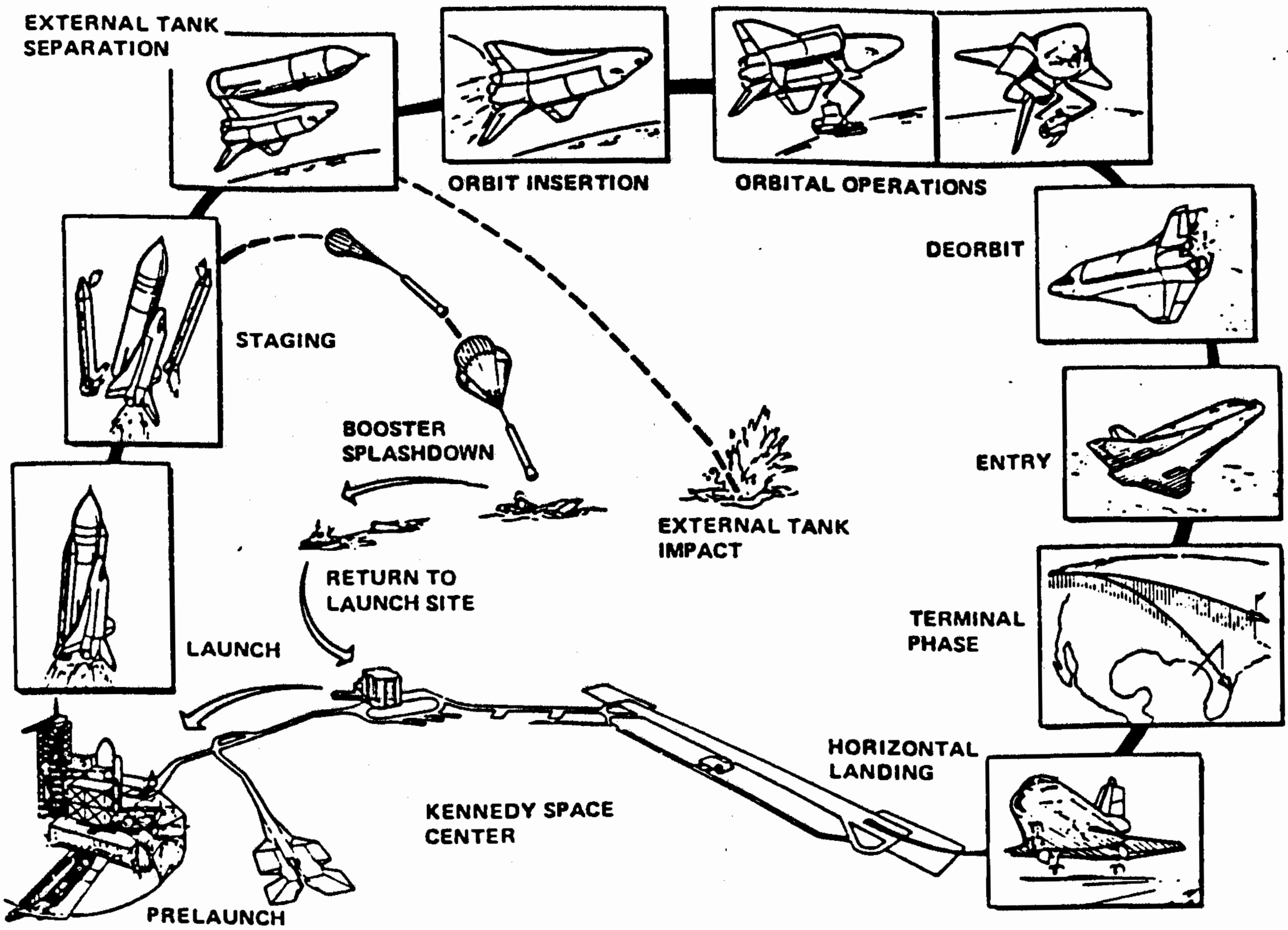


Figure 10

Figure 10 is taken from the space shuttle news reference, by the national Aeronautics and Space Administration, NASA, (1990).

Space Shuttle Mission Profile



A Space Shuttle typical mission profile.

Figure 11

Figure 11 is taken from the space shuttle news reference, by the national Aeronautics and Space Administration, NASA, (1990).

Orbital Dynamics

To determine feasibility and develop selection criteria, time was spent investigating orbital dynamics. Orbital Dynamics provided definitions and destinations for the orbits available. This information served as aid in developing vehicle selection criteria. (Pocha, 1991) identifies several orbits, begining with, low earth orbit(LEO). Any vehicle traveling in (LEO) will circle the earth at altitudes between 200 and 1000 Km with a low or moderately low inclination to the equatorial plane with moderate eccentricity.

Polar orbits (PO) have high inclinations. These inclinations cause vehicles to orbit over the poles of the earth.

Highly eccentric orbits (HEO) come near the earth at closest approach (perigee). (HEO) causes a space vehicle to move very far away on the opposite side (Apogee).

Geostationary earth orbit (GEO) has zero inclination and a period equal to the earths rotational period. This orbit is used in conjunction with the geostationary transfer orbit(GTO). (GTO) is an eccentric orbit designed to position space vehicles or satellites for (GEO).

Knowledge of the effects of gravitational forces acting on the launch vehicles are a function of orbital dynamics. It takes a large amount of energy to send a vehicle into space. This is because several forces will act on the vehicle during travel.

These forces include the sun and moons gravitational forces. The uneveness of earths gravitational field. The solar winds also act on vehicles causing small pressure to the exterior of the vehicles during transport. The combination of all three of these forces will cause extra fuel to be expended to compensate and overcome forces.

Our concern with transporting (LLRW) to outer space would be expending the propellants prior to reaching deep space. Deep space is approximately 20,000 Km which exceeds any of the low earth orbits discussed earlier. According to NASA, vehicle entering deep space will not re - enter earth orbits or biosphere.

Chapter III

STATEMENT OF PROCEDURE

The procedures of this study involved phone calls, library research, personal interviews, correspondence through the mail and field trips. Initially the research started by applying for the Iowa Space Grant Fellowship and Scholarship Program through the Iowa Space Grant College Consortium (See appendices).

In order to qualify, graduates were asked to write a proposal for research. The proposal was centered around investigating the feasibility of disposal of hazardous waste in outer space. In efforts to narrow this area of study a decision was made to identify the waste presenting the most problems to earths biosphere.

Upon completion of several searches through the Deere and Company Library and the University of Northern Iowa library, LLRW and HLRW was identified. These wastes are considered hazardous due to their ability to remain radioactive for long periods of time.

Additional interviews were made through a series of phone calls to individuals from the following organizations.

1. Johnson Space Center
2. Lewis Research Center
3. Kennedy Space Center
4. Cape Canaveral
5. Deere and Company Library
6. College of Natural Sciences, University of Northern Iowa

After contacting the various organizations for answers to specific questions, the study was performed, using descriptive research techniques. This study focussed on disposal of LLRW as a long term solution to earths hazardous waste problem. Information was gathered identifying industries contributions for continuous generation of waste. The following industries were identified as major contributors.

a. Medical

b. Industrial

c. Academic

d. Utilities

This effort was necessary for determining the types of waste, the quantity of wastes and where they are produced. The next phase of research involved gathering information from NASA regarding types of space transportation vehicles. Two types of space transportation vehicles were identified. These vehicles are the space shuttle and the expendable launch vehicle. The space transportation vehicles were analyzed for payload carrying capacity, range and cost to transport per unit weight.

CHAPTER IV

REPORT OF FINDINGS

This research covered three alternatives for removing hazardous waste from earth to outer space. Method number one dealt with incorporating the space shuttle technology and special packaging. The special packaging protects the passengers on the staffed vessel, from radiation during transport. The second alternative dealt with the use of ELV's (Expendable Launch Vehicles) to transport payloads into earth orbit. This alternative may prove to be lower cost and less risky when hauling hazardous items because this vehicle is unmanned. The third alternative dealt with some technology that was used by German scientist during World War Two. This apparatus is called a magnetic cannon or a rail accelerator. The rail accelerator uses a series of coils and voltage to cause a magnetic field force that allows the cannon to shoot projectiles at great speeds and distances.

Field Trip Results

An interview was held with Mr. Ed Wybranowski about the possibilities of using expendable launch vehicles for transporting LLRW into outer space. His initial response was one of uncertainty. Mr. Wybranowski questioned the possibilities of life forms in the solar escape orbit. He was concerned about the ethical issues and the potential for damage to unknown life forms that may be in existence in the solar escape orbit.

This field trip was very informative because it allowed direct observation of the methods and procedures that involve rocket assembly for expendable launch vehicles. This method of removing waste can be cost prohibitive as shown in figure 3 of page 10. For example we can see a significant difference between a pegasus versus the atlas centaur launch service cost when observing the chart. As we increase the amount of payload cost of the launch vehicle will rise accordingly.

ELVs Observed While on Field Trip

The ELV is currently in used to deploy communications satellites. While visiting Cape Canaveral, the Atlas Centaur and Delta rocket launch pads were observed. Both rocket launch sites were busy preparing commercial payloads for transport.

According to Mr. Wybranowski, NASA serves as a consultant in launching space cargos. Their role is to ensure tasks are progressing, to accomplish the mission planned by contractors. Currently, the Atlas Centaur is handled by General Dynamics(contractor).

Besides observing and getting a better understanding of rocket technology, cost information was gathered. Estimated costs to develop a rocket to send significant amounts of LLRWinto outer space would range from 60 to 80 million dollars. A proposal was presented to send 15,000 pound payloads of material into outer space. These payloads would need to exceed low earth orbit. With the current rocket vehicles available, this would be an impossible task. It would be costly and unsafe to provide the amount of propellant needed to launch payloads of this magnitude in to deep space according to Mr. Wybranoski.

A counter proposal was recommended that would require an ELV to rendezvous with the space shuttle. Another idea allows the shuttle to transport and deploy the ELV from the cargo bay into outer space. Upon deployment of the ELV from the cargo bay, the ELV could be ignited for further travel into deep space. When consulting NASA personnel about this proposal they did not think it was impossible conceptually. However, more time is needed to prove reliability of the space shuttle to insure avoiding a possible mishap.

Time was spent visiting the Kennedy Space Center. NASA personal were unavailable for consultation with the researcher because they were preparing to launch the Atlantis. While visiting the Kennedy Space Center time was spent inside an existing space shuttle used for tour purposes. This gave the researcher some additional insight regarding the size of the cargo bay and the living quarters for the astronauts.

STS: Role From Shuttle Payload Integration

Before launching payloads in the space shuttle, the payload must under go a preparation process. This process allows the integration of payloads under the established guidelines of the Space Transportation System (STS). STS customers develop payloads based on the STS handbooks and customer guidelines. These tools are used to describe the STS capabilities and limitations. The Department of Defense (DOD) and NASA customers submit requests on projected launch requirements. The requests are submitted before specific payloads are defined to allow long range flight assignment planning. There are forms that are provided by STS to complement these activities. The forms are located at the Johnson Space Center (see appendices for sample forms).

Hazardous Waste Sources

To address this concern, an effort was made to identify some hazardous waste in storage and out of production. One such substance is agent orange, used as a defoliant in the Vietnam war. Currently, large quantities of this chemical herbicide are stored at a substantial yearly cost to taxpayers. These storage costs are on - going for the chemical defoliant 2,4,5- T (Ray, 1990).

One of the firms authorized to store this material is in LaPorte Texas. The researcher contacted the firm for the purpose of determining cost to store herbicides. This facility currently stores all of the available chemical defoliant 2,4,5- T. The estimated yearly cost to operate this facility is $ 400,000.

CHAPTER V

CONCLUSIONS

Will (LLRW) disposal in outer space have any adverse effects on earth?

Yes, if mishaps occur during launch or after launch catastrophic damage could result. When disposing of hazardous waste in outer space, the objective is to ensure that there is no chance of the material returning to our biosphere. This requires exploration and study of where to send this material.

To determine the best location, a letter was written to the Lewis Research Center in Washington D.C.(see appendices). Blair L. Labarge, a NASA engineer, sent information that explains the type of orbital dynamics necessary to dispose of LLRW. The recommended orbit is called the solar escape orbit. Most earth orbits would eventually allow LLRW to re - enter the earth's biosphere. Keeping this restriction in mind, vehicle and payload size must be selected accordingly.

The next concern would be precautionary measures in the event of a mishap. It may be necessary to provide some special high impact resistant packaging and processing to prepare the LLRW for transport. This is necessary to avoid the potential for spreading waste over highly populated areas.

Finally, we must use the same precautionary packaging material when transporting the hazardous waste from its origin to the launch site. Transport over land can only occur in areas that are not highly populated.

What potential financial benefits result from disposal of LLRW in outer space?

There are considerable financial benefits involved with the safe removal of LLRW. One of the most expensive problems associated with the evolution of nuclear power plants is their inability to dispose of the LLRW generated. This expense has caused some plants to experience difficulties in getting the necessary permits to expand. Some plants have closed temporarily until additional storage or dump sites are located.

Additional financial benefits are formed by not allowing our natural resources to be developed as storage sites. These storage sites are staffed and monitored constantly. Large sums of money are paid to states agreeing to serve as compacts. Compacts are states that agree to be responsible for storing LLRW for surrounding states. These compacts are often funded and monitored by the federal government. It is the researchers opinion that if we dispose of this material instead of storing it, the cost benefits can be recognized.

What is the cost of current methods of disposal? The approximate cost of current methods of disposal is difficult to capture therefore, the researcher will site one example previously mentioned. The Yuka Mountain facility, while not complete yet, has cost the tax payers approximately $1 billion. There are already signs of harm to natural resources that cannot be replaced. Once a natural resource is damaged or destroyed there is no tangible value assignable.

What kind of processing is required before transport

It will be necessary to provide some type of protective high impact packaging. The packaging will feature a drogue chute and some type of homing device if a mishap occurs. This homing device could transmit a signal to provide the ability to recover lost cargo if missions are aborted for any reason. If we are using a staffed space craft, special precautions must be in place to protect crew members. Robots may be necessary to perform processing operations to limit human exposure.

Recommendations

1. NASA should reopen the efforts to develop the rail accelerator as a cheap means of launching payloads. A vehicle of this type could allow utility companies and industry to play a more active role in managing the LLRW they produce.

2. Additional efforts should be made to develop technology using LLRW because it is not as hazardous to human life should a mishap occur. After debugging the procedures for disposal of LLRW, these same procedures should be investigated for other hazardous waste.

3. Further study should be performed to identify the feasibility of using the space shuttle to deploy expendable launch vehicles from its cargo bay. This idea would allow the expendable launch vehicle to reach deep space.

4. A study should be conducted outlining the damage to earth and outer space when using outer space disposal method. Upon completion, the information gathered should be provided to the public. Informing the public will increase awareness and allow the realization of the benefits studied.

References

Aldelstein, J.,& McKusick, K., (1986) Not In My Back Yard Radioactive Waste and Health. The Medical Forum pp.4-6

Commercial Delta II Space Craft User Manual. (1987). Huntington Beach, Ca., McDonnel Douglas Commercial Delta Inc..

Furiga, P.(1989), Hot Stuff, Governing, pp.50-54.

Hamilton, D.P.(1990), News & Comments, p.357.

Kerslake, W.R.,& Cybyk, B.Z.,(1982). Rail Accelerator Research at Lewis Space Center.

Krysiak, J. (June, 1991) [letter from Lewis Research Center].

Lebarge, B. (May, 1991), [letter from Lewis Research Center].

Manastersky, R. (February, 1988) The 10,000-Year Test, Science News(Vol.133) pp.137-141.

National Aeronautics and Space Administration. (1981). Space Shuttle News Reference (publication no. 341-570/3256) U.S. printing office.

Norman, C. (1985, August) Low Level Deadline Looms, Science, (Vol. 229) pp.448-449.

Pocha, J.J., & Parker, I.,(1991, March - April). Understanding Orbital Dynamics. Space, pp. 23-25.

Potowski, K.S., (1988) United States Expendable Launch Vehicle Technology Past, Present, and Future.

Ray J. T.(1989), Hazardous Waste Update Memo, City of Waverly.

Ruppe, H.O.,Hayan, D.,Braittinger, M.& Schumocker, R.H. (1980) A Nuclear waste deposit in space, the ultimate solution for low cost and safe disposal.pp.346-354.

Saleska, S. (1990) Low Level Radioactive Waste: Gamma Rays In The Garbage, The Bulletin of The Atomic Scientist.

Wasserman, H.(1990,January) Dumping on us. The Nation p.76.

Wybranowski, E. (1991), Personal Interview , Cape Canaveral E & O.

Zana, L.M., Kerslake, W..R., Sturman, J.C., Wang, S.Y., & Terdan, F.F.(1982), LeRC rail accelerators test, design,& diagnostic techniques (Report No. 83496) Cleveland Ohio: Lewis Research Center, NASA.

Appendix A

Correspondence

Dear Mr. LaBarg 01 May 1990

Per our telephone conversation I am sending you some more specifics about my area of research as a NASA space grant recipient. Attached is an outline of plans to explore the possibilities of disposing of hazardous waste in outer space. In efforts to accomplish this I am seeking additional information concerning expendable launch vehicles (ELVs).as follows.

1. Cost per pound to transport a sizable pay load.

2. Safety considerations and regulations governing the use of such vehicles.

3. Dimensions type and size considerations and any design criteria for constructing a ELV.

4. If a person wanted to transport low level radio active waste what safety measures are necessary.

5. I would like some illustrations of the mechanics behind ELVs and there current use and application.

In addition to the above items requested I would like to know if a trip to see your facility and observe some ELV technology would be possible. I could probably set aside a week for a visit to your facility in efforts to complete my research as a NASA fellow. Please reply in writing if any of the above is possible. Thank you in advance for your cooperation and interest.

Sincerely

Michael S. Cook

Date 20 August 1991
Michael S. Cook
PH. 232-4432
426 Shirley St.
Waterloo , Iowa
50707

Dear Ed Wybranowski

I would like to thank you for spending time with me during my visit to Cape Canaveral. I've become more knowledgeable about expendable launch vehicle technology. I will use the information you supplied to answer some research questions about cost and reliability. After your tour I spent time at the space museum and the Kennedy Space center. This allowed me to observe some additional rocket technology in addition to walking inside of a replica of the space shuttle. I would also like to thank you for the additional contacts and literature you provided, this information will be very useful.

Once again thanks for making this a meaningful trip. If you can think of any additional information that may assist me in my endeavors please feel free to call me, Michael S. Cook.

Sincerely Yours

Michael S. Cook
NASA Fellow

National Aeronautics and
Space Administration

Lewis Research Center
Cleveland, Ohio
44135

Reply to Attn of 9410 June 17, 1991

Mr. Michael S. Cook
426 Shirley Street
Waterloo, IA 50707

Dear Mr. Cook:

In response to your request for information concerning the state of rail accelerator research at NASA, NASA has not done any work in this area since 1984. Mr. William Kerslake (retired), who formerly worked on this project, has given me the following information for you:

The study design would have required an energy expenditure of 600,000 kilojoules at a current of 28,000 kiloamps for a payload projectile of 2,000 kilograms. This apparatus would have cost less than $8 billion, and it would have required a 100 man space station as support. Since this apparatus would have required a 40 year time to readiness due to the numerous technical advances required for it, the program was cancelled in 1984. Your concept of ejecting hazardous waste into the sun by means of the rail accelerator was examined but discarded. It was determined that toxic waste, especially radioactive nuclear waste, would be easier, by a factor of 2, to dispose of by launching it into deep space rather than into the sun. It was determined that if the nuclear waste were launched into the sun, not all of the waste would be incinerated by the sun. A small amount of the waste would be captured by the solar wind, and it could be returned to the earth.

We have enclosed two technical memoranda on rail accelerator research that should answer any further questions that you may have. The test facility initially employed at the Lewis Research Center required an energy expenditure of 5 kilojoules at a current of 50 kiloamps for a payload projectile of about 0.06 grams. The larger and final test facility employed at the Lewis Research Center required an energy expenditure of 60 kilojoules at a current of 400 kiloamps for a payload projectile of about one gram.

We hope that this letter and the reports answer the questions which you may have on rail accelerators. We appreciate your interest in the research that has been conducted at the Lewis Research Center.

Sincerely yours,

Joseph E. Krysiak
Technology Utilization Engineer

Enclosures

NASA

National Aeronautics and
Space Administration

Washington, D.C.
20546

Reply to Attn of MLP

MAY 8 1991

Mr. Michael S. Cook
426 Shirley Street
Waterloo, IA 50707

Dear Mr. Cook:

I apologize for the delay in responding to your request for information dated April 16, 1991. The amount of information which you have requested is extensive, and my response to you at this point can only be of a most general nature. With regards to your specific questions:

1. Enclosed is a chart which shows the different U.S. expendable launch vehicles (ELV's) currently in use, their mass capabilities to different orbits, and the range of launch costs for each. Launch costs vary depending on the type of mission. To determine a very rough pound-to-orbit cost for each ELV, divide the launch cost by the mass capability to a particular orbit. A word of caution, however--my sense is that the type of payload you are interested in (low-level radioactive waste disposal) would require an earth-escape orbit, which this chart does not reflect. This is because the vast majority of payloads do not require earth-escape trajectories but are rather launched into one or another type of earth orbit. The only NASA spacecraft which requires earth-escape trajectories are interplanetary probes, such as Pioneer, Voyager, etc. In case you are unfamiliar with the various earth orbits, I am enclosing a recent article from the magazine Space which describes them.

2. The range and safety regulations which govern ELV launches are voluminous, and comprise NASA, Department of Defense, and Department of Transportation regulations (the latter for commercial ELV launches). For specific information I would direct you to the Office of Safety & Mission Quality here at NASA Headquarters, as well as to the Office of Commercial Space Transportation at the Department of Transportation.

3. See response to question 5.

4. The transportation of radioactive waste is regulated principally by the Department of Energy, and questions on this subject should be directed to them.

5. Enclosed for your further information on the use and function of ELV's is a copy of a paper, "United States Expendable Launch Vehicle Technology Past, Present, and Future", authored by Karen S. Poniatowski of this Division. Please reference Ms. Poniatowski as the source if you should cite the contents of her paper in your report.

You also mentioned an interest in visiting a NASA facility to "observe some ELV technology". Here at NASA Headquarters there is nothing more interesting to observe than offices, but you would undoubtedly find a trip to the Kennedy Space Center in Florida useful. A visit there with NASA employees who handle ELV launches of NASA payloads can be arranged if you wish.

Sincerely,

Blair L. LaBarge
Unmanned Launch Vehicles
and Upper Stages Division
Office of Space Flight

Enclosures

Michael

I am sending some copies of documents that may help you understand the space shuttle operations and payload integration process.

I have made a few calls regarding the documents you list and have been told they are not made available unless you have a contract with NASA to build and fly a payload, Then you only get those that are of interest, not the entire package what you are asking for would fill a bookshelf

I am also sorry to have misled you in regard to a tour of J.S.C and the facilities you are interested in. There is a public tour that is open every day for certain buildings and exhibits but special tours are very limited to groups of VIP doing special programs and again to those who are doing business with J.SC in some capacity.

For more information you may call the numbers listed on the second page.

Keith Henderson

JSC Numbers

Public Affairs Library 713-483-8694

Public Affairs Tours 713-483-4321

Headquarters

Expendable Launch Vehicles

Charles Gunn 202-453-8719

APPLICABLE DOCUMENTS

The following documents list mandatory methodology and procedures for all payloads to be flown aboard the Shuttle.

NSTS 1700.7B	Safety Policy and Requirements for Payloads Using the National Space Transportation System (NSTS).
KHB 1700.7A	Space Transportation System Payload Ground Safety Handbook
SAMTO HB S-100	Air Force Range Safety Handbook
JSC 14046	Payload Interface Verification Requirements
NSTS 07700 VOL. XIV REV. J	Space Shuttle System Payload Accommodations.
NSTS 21000-IDD-SML	Small Payloads
NSTS 21000-IDD-MDK	Middeck Payloads
ICD A-14021	GAS Payloads and Hitchhiker G&H Payloads
	It is expected that nearly all OAST IN-STEP sponsored STS payloads will utilize Orbiter/Payload Interface Documents based upon one of the above standard ICD formats.
MSFC-SPEC-522B	Design Criteria for Controlling Stress Corrosion Cracking.
MSFC-HDBK-527/ JSC 09604	Materials Selection List for Space Hardware Systems (MSFC and JSC versions of the same document)
NHB 8071.1	Fracture Control Requirements for Payloads Using the National Space Transportation System (NSTS).
	Although the requirements of this document are mandatory for STS payloads, use of these design principles for ELV payloads results in a significant increase in mechanical reliability of any payload.
MIL-STD-1576	Electroexplosive Subsystem Safety Requirements and Test Methods for Space Systems.

Safety and test verification complications resulting from the use of pyrotechnic devices should result in careful consideration of all alternative design solutions, so that the use of these devices is clearly the only way to perform the experiment.

NHB 8060.1	Flammability, Odor, and Offgassing Requirements and Test Procedures for Materials In Environments that Support Combustion. This document is especially appropriate for STS middeck payloads.
MIL-STD-1522A	Standard General Requirement for Safe Design and Operation of Pressurized Missile and Space Systems. Always imposed on any sealed container of fluids carried on the Orbiter middeck.

REFERENCE DOCUMENTS

The following publications have been published as an aid in development of safe payloads which will interface with orbiter services. Their use is recommended but not mandatory.

JSC 13830	Implementation Procedure for NSTS Payloads System Safety Requirements
JSC 11123	Space Transportation System Payload Safety Guidelines.
GSFC GEVS-STS	General Environmental Verification Specification For STS Payloads, Subsystems, and Components. This Goddard Space Flight Center specification provides direction concerning administration and management of a complete test program and test levels for all applicable parameters. It is expected that the managing NASA Center of each payload will provide a similar specification to allow realistic planning and cost estimation of the flight qualification portion during the phase B study.
GSFC 731-0005-83	General Fracture Control Plan For Payloads Using the Space Transportation System.

2/7/91

Dear Mike -

Have been unable to get through to you by phone. It was suggested that you do a literature search through the National Technical Information Service at GSFC. If your a NASA Fellow, you should be able to get a password & get access to the system via telephone. My source has been working exclusively with Shuttle and Delta launch vehicles. She said she had no general report(s) summarizing launch vehicle capabilities.

Relative to other references on requirements for STS/ELV's, I've enclosed pages from a recent NASA Announcement of Opportunity for In-Space Experiment. Some of these may be relevant to your area of interest.

Best of luck.

Bill Bifans

Chief, In Space Technology Branch
Mail Stop 500-217

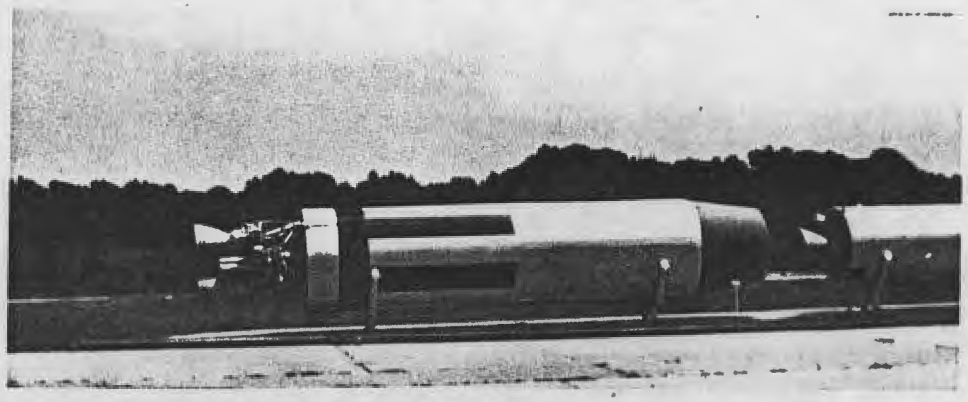
Appendix B

Pictures Taken During Field Trip

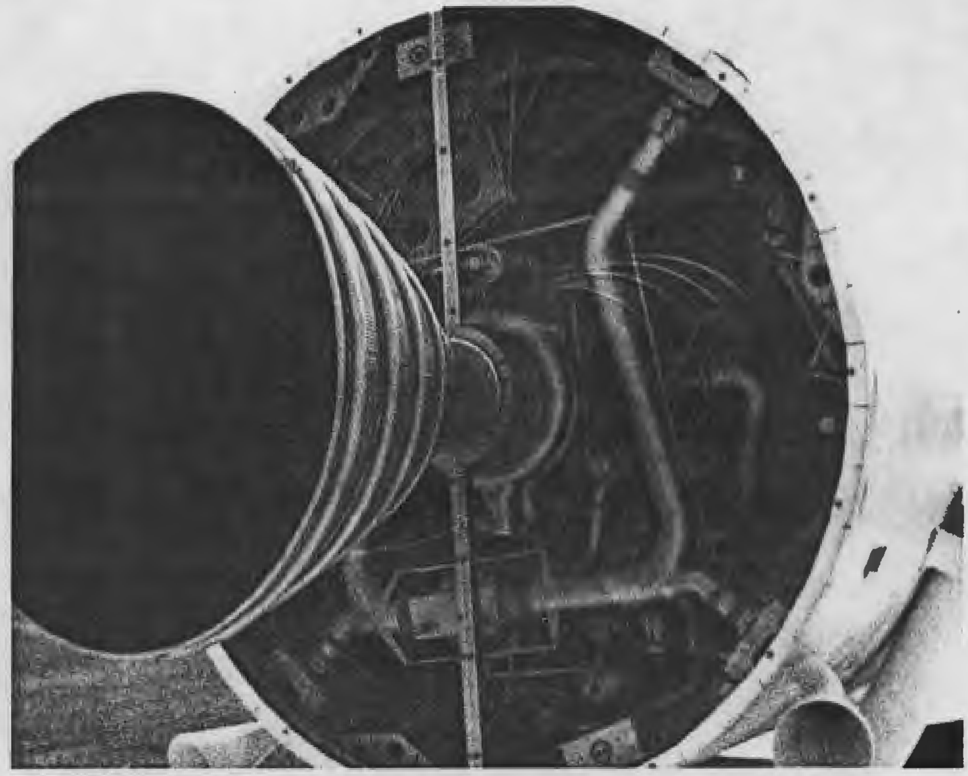
U.S. Air Force Ballistic Missal.

Close up example of a rocket transport trailer.
This trailer assists with the positioning and transporting of the vehicles to a vertical position prior to launch.

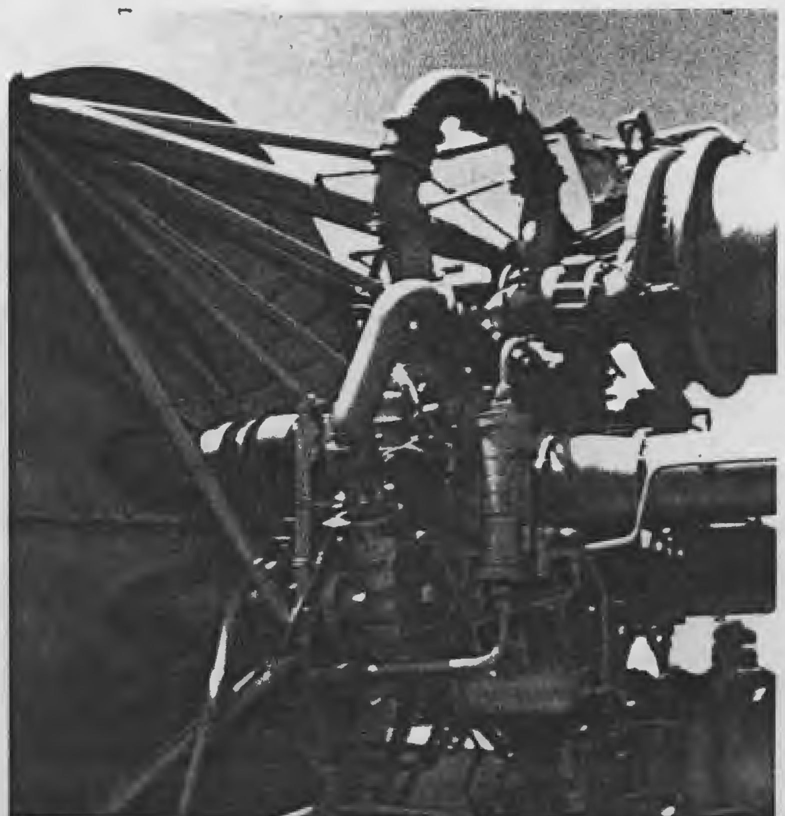
Titan I Two Stage Rocket.



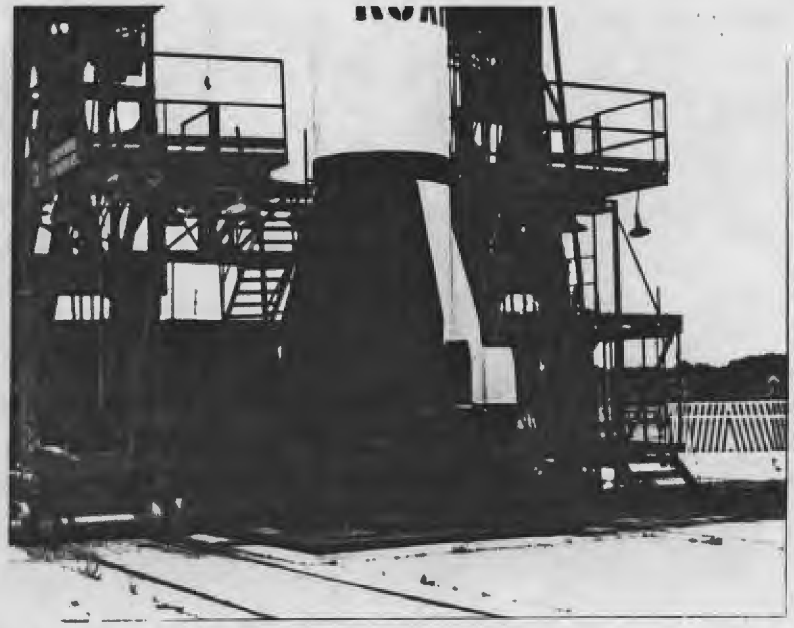
The first stage and the beginning of the second stage of a Titan I rocket display.



Titan I first stage rocket engine. Notice the rocket thrusters used to guide and control spinning.



Side view of rocket guidance and control system.



Close up view of the base of an assembly tower or often called MST (Mobile Service Tower)

Side view of a rocket assembly tower or MST

Appendix C

Copy of Research Grant Application

ANNOUNCEMENT

1991/1992
IOWA SPACE GRANT FELLOWSHIP AND SCHOLARSHIP PROGRAM

GRADUATE/UNDERGRADUATE

Request for Applications

NATIONAL SPACE GRANT COLLEGE AND FELLOWSHIP PROGRAM
NASA

Iowa Space Grant College Consortium

IOWA STATE UNIVERSITY
UNIVERSITY OF IOWA
UNIVERSITY OF NORTHERN IOWA

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
NATIONAL SPACE GRANT COLLEGE AND
FELLOWSHIP PROGRAM

Application Deadlines:
Graduate Fellowships - March 20, 1991
Senior Scholarships - April 3, 1991

Dr. Gerald R. Intemann, UNI Coordinator
Acting Dean, College of Natural Sciences
50 Biology Research Complex
University of Northern Iowa
Cedar Falls, IA 50614-0181
Phone: (319) 273-2585 FAX: (319) 273-3509

The Space Grant Fellowships and Scholarships awarded by the Iowa Space Grant College Consortium will be awarded through the Consortium Program Office by the Executive Committee and administered through the Campus Coordinator on whose campus the fellow or scholar is working.

Names and Locations of Field Centers of the National Aeronautics and Space Administration

George C. Marshall
Space Flight Center
Mail Stop DS01
National Aeronautics
and Space Administration
Huntsville, AL 35812

Goddard Space Flight Center
National Aeronautics and
Space Administration
Code 600
Greenbelt, MD 20771

Lyndon B. Johnson Space Center
Mail Code AHU
National Aeronautics and
Space Administration
Houston, TX 77058

Lewis Research Center
Mail Stop 3-7
National Aeronautics and
Space Administration
21000 Brookpark Road
Cleveland, OH 44135

Ames Research Center
Mail Stop AHT-241-3
National Aeronautics and
Space Administration
Moffett Field, CA 94035

Jet Propulsion Laboratory
Mail Stop 180-900
4800 Oak Grove Drive
Pasadena, CA 91109

Langley Research Center
Mail Stop 105-A
National Aeronautics and
Space Administration
Hampton, VA 23665

J. C. Stennis Space Center
National Aeronautics and
Space Administration
Stennis Space Center, MS
39529

SUBMISSION OF APPLICATIONS

APPLICATIONS
Applicants for the new or renewal awards under this program should submit six copies of all materials by the program deadline to the Campus Coordinator where the applicant expects to undertake studies for a degree program and carry out the research program or plan of study. The names and addresses of these individuals are listed at the beginning of this instruction packet. After preliminary screening by the Campus Coordinator, applications for final consideration will be forwarded by the Campus Coordinator to the Consortium Program Office. The selection of the successful applicants will be made by the Executive Committee which represents all three institutions. Successful applications will be announced about ten days after the application deadline. Proposed starting dates for new and renewal awards will generally be expected to coincide with normal academic term starting dates. The renewal application should include a brief statement outlining the academic progress and status of the research program or plan of study, documentation of accomplishments, academic grades for the previous year and two letters of recommendation from faculty personnel.

FINAL ADMINISTRATIVE REPORT
A report on the student's research and academic progress must be submitted by the faculty advisor within sixty days of completion of the student's study and research program. Information to be furnished in the report includes the degree granted, the employment or career plans of the student, and other important results of the student's experience, e.g., thesis or dissertation title, papers published or written other than the thesis or dissertation, presentations made, awards, and honors.

One copy of the report should be sent to the Consortium Program Director (along with a bound copy of the earned thesis or dissertation) at the Consortium Program Office and one copy to the appropriate Campus Coordinator.

INQUIRIES
Questions concerning the preparation and submission of applications and the administration of this program should be addressed to the appropriate Campus Coordinator listed at the front of this instruction packet or the Consortium Office at Iowa State University.

ADMINISTRATIVE PROCEDURES

SELECTION OF PROPOSALS
NASA Space Grant Fellows will be selected for participation in the Fellowship Program by the Consortium Executive Committee. Selection will be based on 1) the academic qualifications of the applicant, 2) the quality of the proposed research program and its relevance to NASA's aerospace science and technology program, 3) the quality of the interdisciplinary approach to achieving the objectives of the proposed program, 4) the prospects for completion of the project within the allotted time, and 5) an assessment of the applicant's motivation toward an aerospace career.

AWARDS
All graduate awards are made initially for a 12-month period (except those applicants who may graduate or complete the academic program in less time). Some are renewable for a maximum of 24 months. Renewals are based upon favorable annual reviews and approvals by the faculty advisor and the Space Grant Program Office. Fellows will be expected to devote full time to graduate study and research during the tenure of the fellowship.

All undergraduate awards are made for one academic year. However, if eligible, the awardee may apply for an award for a second year.

ELIGIBILITY
Applicants for the Fellowships must be citizens of the United States and those for the Scholarships must be citizens or permanent residents of the United States.

For the Graduate Fellowship Program, applications may be submitted prior to completion of the senior undergraduate year or at any time during the applicant's graduate career. Beginning graduate students must show evidence of having met the entrance requirements of the institution in which they propose to enroll. Graduate students at a member institution may apply for an award at that institution or at another member institution. Full-time graduate students from a college or university that is not a member of the Consortium are eligible to apply for awards if they are able to meet the entrance requirements of the Consortium member university at which the applicant proposes to study. Graduate Fellow Designees, in agreement with the Campus Coordinator of their institution, may initiate their programs at any time during the year.

Applications for the Undergraduate Scholarship Program may be submitted as early as the final term of the sophomore year. Undergraduate Scholar Designees may not initiate their studies prior to the beginning of their junior year and must be classified by their institution as a junior or senior during the term of the award.

Each application must be sponsored by the involved department chair and a faculty advisor from the consortium member institution where the student expects to do the research program and obtain the degree. Individuals accepting graduate fellowship awards cannot receive concurrently other federal funds (including funds from other federal fellowships, traineeships, or federal employment) or be otherwise employed.

EQUAL OPPORTUNITY
Applicants will not be denied consideration or appointment as NASA Space Grant Fellows or Scholars on grounds of race, creed, color, age, sex or handicap.

OBLIGATION TO THE GOVERNMENT
While students who receive support through the National Space Grant Fellowship Program (NSGFP) do not incur any formal obligations to the government of the United States, the objectives of the program clearly will be best served if graduates from the program pursue further study or careers in aerospace science and technology fields and support areas.

FUNDING
For Graduate Fellows, total award per student will be $16,000 for 12 months. This award will include $13,000 for student stipend and $3,000 that may be used to help defray tuition costs or other necessary expenses. For Undergraduate Scholars, the award per student will be $1,000 for 12 months. Specific details regarding the extramural experience for graduate fellows will be discussed with the fellows and their faculty advisors after finalizing the fellowship awards.

FELLOWSHIPS AND SCHOLARSHIPS
PREPARATION OF APPLICATIONS

UNSOLICITED APPLICATION REQUIREMENTS
Proposals must be written by the students, should be specific in nature and should be prepared in the following format.

Cover Sheet
This page should be completed and signed by the student, the faculty advisor and the appropriate campus office director responsible for sponsored research. Cover sheet forms are included with these instructions.

Abstract
The abstract, not to exceed 400 words, should describe the objectives of the proposed research program or plan of study and the methodology to be used.

Description of Proposed Research and/or Plan of Study (Graduate Fellowship)
A full statement, prepared by the student, that identifies and relates the key elements of the proposed research and/or any plan of study is required. The statement should include interdisciplinary studies that will enrich the understanding of complex aerospace issue. Total description should not exceed the equivalent of five typed, single-spaced pages and must include a clear statement of how the proposed research or study plan will help meet the objectives of the NSGFP.

Schedule of Target Dates (Graduate Fellowship)
The starting and completion dates for the proposed research program or plan of study, including the expected date for completion of the formal degree program, should be identified realistically.

Description of Proposed Study (Undergraduate Scholarship)
A statement, expanding on the abstract, prepared by the student, that identifies the key elements of the proposed special study that will be conducted. The statement should emphasize new areas that will be included. Total description should not exceed the equivalent of two typed, single-spaced pages.

Personnel
Resumes of the applicant and the faculty advisor should be included with the proposal. The student's resume should include a short summary of education, training and accomplishments. Resumes should not exceed two typed pages.

References
The faculty advisor should provide a recommendation as to the acceptability of the student for the program, a clear statement of the advisor's willingness to supervise the student, and the nature of any past or present experience with the student. A second letter of recommendation should also be provided.

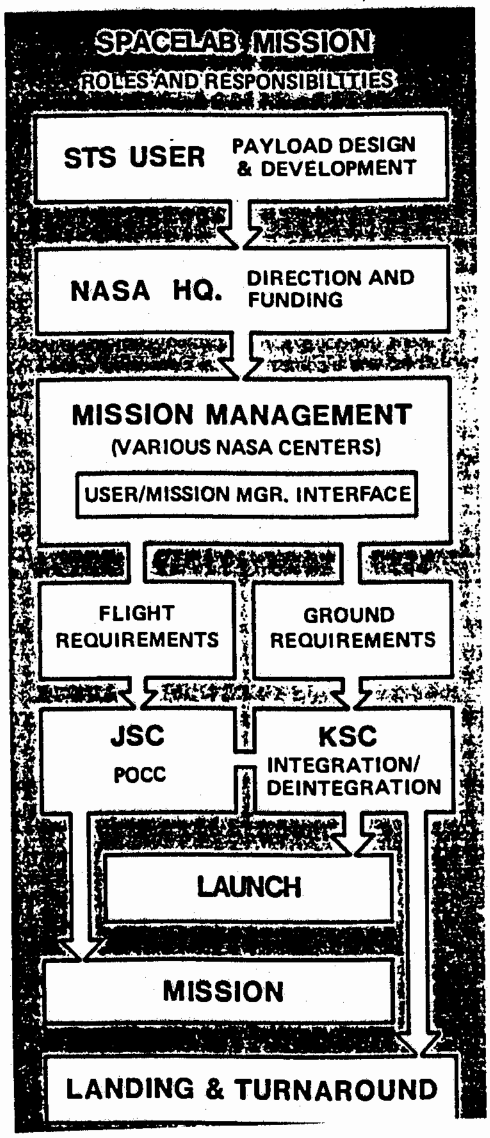
Approval
Signatures and phone numbers for approval should be consistent with those on the cover sheet and must also include the name, phone number and signature of the appropriate department chairperson. Proposals cannot be processed without these approval signatures.

Disposition of Unused Funds
If a student terminates the Fellowship or Scholarship Program earlier than anticipated, the student stipend and other allowances are prorated and terminated. Any unused stipend and allowances are returned to the Consortium Program Office.

Appendix D

Copy of STS Forms

SECTION THREE: PLANNING AHEAD III



In this guide, we have presented an introduction to the basic steps involved in processing your payload and at the same time identified some of the more important considerations that will help you during the ground integration phase of your flight. In essence, there are two areas in which STS users can participate prior to arrival at KSC to help ensure trouble-free and economical ground processing of their payloads.

First is a working knowledge of launch site capabilities. This will be developed through discussions with your mission manager, through documentation that he will supply, and during meetings here at KSC that you or representatives for your payload will attend. This will give you a better understanding of some of the restrictions and limitations imposed on STS payloads by preflight processing and may provide useful information for the final design of flight hardware and support subsystems.

Second, there is the need for early identification of payload requirements that may affect processing at the launch site. These requirements may be identified by you as they become apparent, or they may come to light as a result of KSC analysis of your payload design and test and checkout needs. In either event, their timely satisfaction will depend on information supplied by you to your mission manager.

In closing, it should be noted that there will be no "final approach" to the processing of Space Shuttle payloads. Facilities, equipment, and procedures at KSC will constantly evolve and mature in response to advances in the Shuttle vehicle as well as in the nature of the payloads themselves. The future evolution of Spacelab, large space structures, space manufacturing facilities, space stations, and geosynchronous operations will all impose new requirements on the STS program in general and on launch site support in particular. NASA has already begun to study spaceport development into the 21st century, and by working together we can ensure that the STS program will continue as an efficient and profitable venture for all concerned.

NASA National Aeronautics and Space Administration

Request for Flight Assignment

Form Approved
O. M. B. No. 2700-0040

CONTROL NO. *(MC Use)*

Note.- Please read and detach instructions before completing this request.

TO	National Aeronautics and Space Administration Customer Services Code MC Washington, DC 20546	FROM	DEVELOPMENT COMPANY/AGENCY NAME AND ADDRESS PRINCIPAL CONTACT *(Name and Phone, incl. Area Code)*

I-BASIC PAYLOAD AND FLIGHT DATA

1. PAYLOAD TITLE

2. PAYLOAD OBJECTIVES

3. CATEGORY

☐ a. U.S. COMMERCIAL ☐ b. DOD ☐ c. NASA ☐ d. FOREIGN COMMERCIAL

☐ e. FOREIGN GOVERNMENT ☐ f. OTHER U.S. GOVT. ☐ g. JEA/OTHER

4. FLIGHT INFORMATION *(Check at least one in items 1-4)*

1 ☐ a. SHARED ☐ b. DEDICATED

2 ☐ a. CARGO BAY ☐ b. MIDDECK *(Specify locker volume)*: ____________

3 ☐ a. ATTACHED ☐ b. DEPLOYABLE ☐ c. RETRIEVAL ☐ d. REVISIT/SERVICE

4 ☐ a. KSC ☐ b. VLS

5. CARRIER

☐ a. PAM D ☐ b. PAM DII ☐ c. IUS

☐ d. MPESS ☐ e. HITCHHIKER-G ☐ f. HITCHHIKER-M

☐ g. SPACELAB *(Specify; e.g., LM&P)* ____________ ☐ h. OTHER *(Specify)* ____________

II-PAYLOAD REQUIREMENTS

6. PAYLOAD ORBIT REQUIREMENTS

☐ a. 160NM ALTITUDE/28.5 INCLINATION ☐ b. 160NM ALTITUDE/57 INCLINATION

☐ c. OTHER: (1) NM ALTITUDE _____; (2) DEGREES INCLINATION _____ ☐ d. ORBIT INSENSITIVE

7. PAYLOAD LAUNCH REQUESTED *(Total launch(es) and date(s)) (Enter month and year only)*

a. NUMBER OF LAUNCHES ____________________

b. FIRST LAUNCH *(Scheduled, stand-by, or short-term call-up)* ____________________

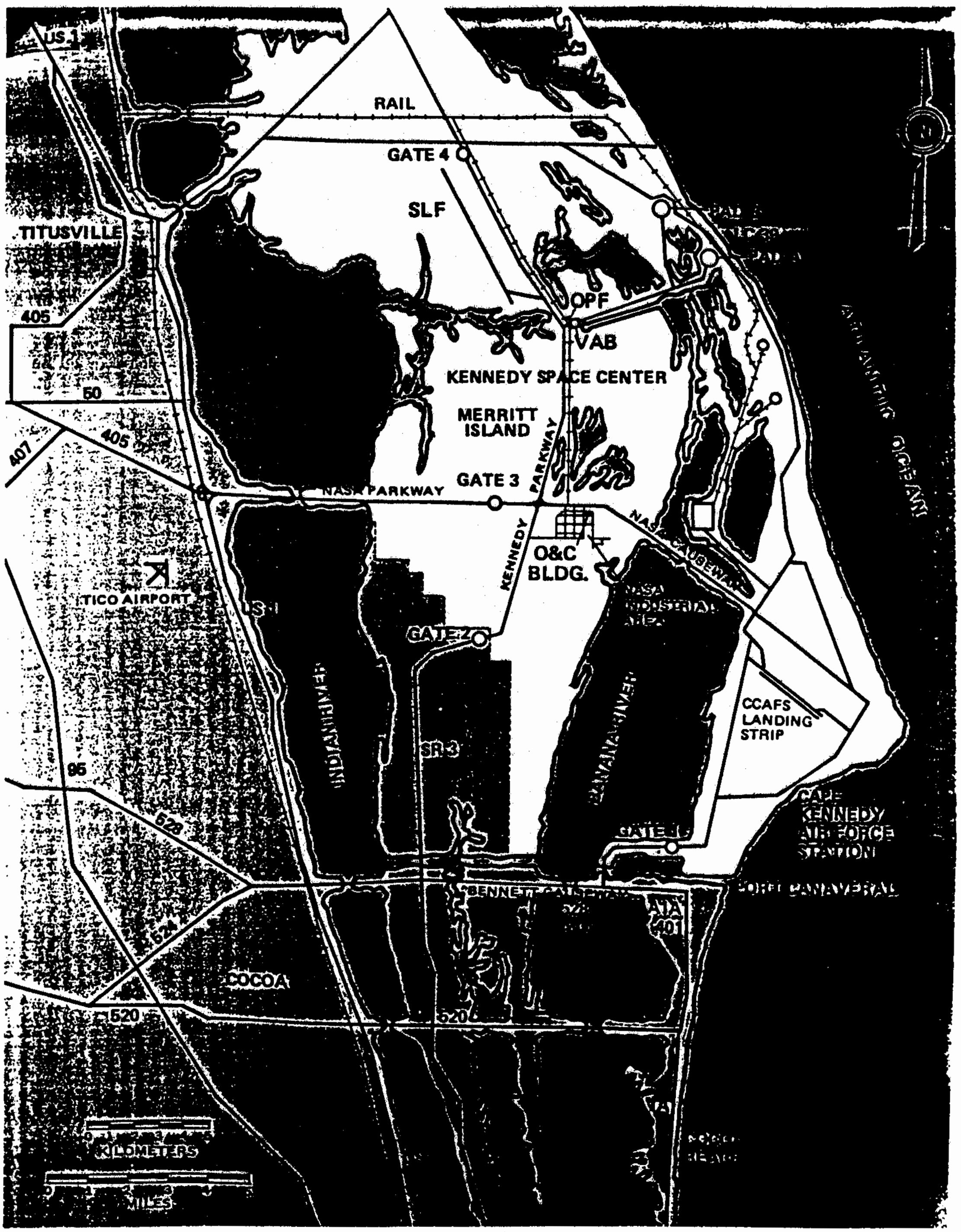
c. SUBSEQUENT LAUNCH(ES) ____________________

____

d. MINIMUM INTERVAL REQUIRED BETWEEN LAUNCHES ____________________

NASA FORM 1628 SEP 86 *(Formerly STS Form 100)*

Figure 6-2.- Request for Flight Assignment (NASA Form 1628).


US 1
RAIL
GATE 4
SLF
TITUSVILLE
405
50
405
407
OPF
VAB
KENNEDY SPACE CENTER
MERRITT ISLAND
GATE 3
NASA PARKWAY
KENNEDY PARKWAY
O&C BLDG.
NASA CAUSEWAY
TICO AIRPORT
US 1
GATE 2
SR 3
INDIAN RIVER
BANANA RIVER
CCAFS LANDING STRIP
CAPE KENNEDY AIR FORCE STATION
GATE 1
PORT CANAVERAL
ATLANTIC OCEAN
95
528
BENNETT CAUSEWAY
A1A
401
COCOA
520
520
KILOMETERS
MILES