



## COLORADO OFFICE OF SPACE ADVOCACY

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January 16, 1996

NASA/MSFC  
Attn: PS05 / Joe T. Howell  
Marshall Space Flight Center, AL 35812

**Subject: Transmittal of Deliverable re Purchase Order No. H-25797D  
(Interim Report)**

Dear Mr. Howell:

COSA is very pleased to submit this deliverable to NASA/MSFC in regard to **MagLifter Site Investigation, Constructibility Analysis, and Implementation Strategies**. This report contains the 'mid point' results of the Task 1 and Task 3 effort described in the Statement of Work. The final report will contain results from Task 2 and completion of Tasks 1&3.

Distribution of this technical report is shown below.

Sincerely,

A handwritten signature in cursive script that reads "Dr. C. Neil Beer".

Dr. C. Neil Beer  
Director

Distribution:

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**MagLifter Siting Criteria Report  
(MSCR)**

**Phase 1, Task 1.1 Submittal**

**November 28, 1995**

**Submitted by  
M. Slaughter, Geologist/Geochemist  
and P. Burke, Systems Engineer**

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## Introduction

MagLifter, as defined here, is an advanced, earth-bound catapult system to provide the initial lift for earth orbiting vehicles to reduce or eliminate the need for multistage propulsion, thus reducing the cost of orbital space flight. It is presumed that magnetic levitation will catapult the vehicle to a desired initial velocity sufficient for reaching orbit with the vehicles own engines. Of necessity, the system must be located on and around a mountain with sufficient relief to allow the catapult to accelerate the launch vehicle to a sufficient speed in the desired direction to allow it to reach orbit. Such a mountain site must meet criteria consistent with current and future space launch needs and conditions.

It is the purpose of this report to set forth preliminary criteria for choosing a suitable maglifter site. This report represents the initial submittal of the MagLifter Siting Criteria Report (MSCR) for Subtask 1.A of the MagLifter Site Investigation, Constructability Analysis, and Implementation Strategies Study, performed by the Colorado Office of Space Advocacy (COSA) for Marshall Space Flight Center.

The report is divided into four major sections: (1) Assumed Launch System and Flight Vehicle Characteristics; (2) Task 1.A - Initial Site Selection Criteria; (3) Conclusions; (4) Appendix - Phases of the Site Selection Process.

### Assumed Launch System and Flight Vehicle Characteristics

The following is assumed to develop the site characteristics and site selection criteria. Further clarification and enhancement of these assumptions is necessary to support the completion of Task 1 and the performance of Task 2.

#### Flight Vehicle Characteristics:

1. The vehicle will have a rocket or hybrid propulsion system with the following fuels:
  - a. Cryogenic fuels
  - b. Jet fuel
  - c. No hypergolic fuels
  
2. Profile of the vehicle will be aerodynamic with the following dimensions:
  - a. 140 foot length
  - b. 60 foot wingspan
  - c. 20 foot outside diameter for the payload bay/fuselage
  - d. Total weight - about 1 million lbs
  
3. Payload capability:
  - a. 20,000 lbs to low earth orbit (LEO)
  - b. 5,000 lbs to GEO orbit

4. Operation:
  - a. Unmanned
  - b. Single stage operation after separation from catapult sled
  - c. Teleoperation capability for initial stages of flight

**Flight Mode:**

1. Single stage to orbit
2. Flight vehicle returns to site on own power and either lands vertically or on runway as does a conventional airplane.
3. No ferry for vehicle unless alternate landing site chosen

**MagLifter Configuration:**

1. The MagLifter catapult will comprise the following:
  - a. Sled to carry launch vehicle on a track
  - c. Track about three miles long in a tunnel
  - d. Tunnel to be a cut into the mountain with a cover where possible and a tunnel bore where necessary
  - e. Initial span of tunnel slightly inclined or horizontal
  - f. Final span of tunnel inclined equal to or greater than 45°
  - g. Continuation of track beyond the tunnel exit for sled deceleration: 1 to 2 miles
  - h. Magnetic levitation and momentum source for flight vehicle
  - i. Tunnel muzzle or escape velocity of vehicle - 600 mph
  - j. South polar and equatorial tunnel orientations: 150° to 180° azimuth
  - k. Tunnel enclosure with back-flow protection at escape end.
2. Catapult/Vehicle forces will not exceed the following:
  - a. Braking forces not to exceed 3.0 g's
  - b. Curvature of tunnel and track to limit lateral load to 1.5 g's

**Ground Support System:**

1. Launch track as defined above
2. Initial processing facilities located on flat ground away from track
3. Final processing facilities located near entry of launch track
4. Refurbishment/Repair facilities on flat ground
5. Fuel storage on or in flat ground
6. Emergency landing/abort "runway" directly down range of tunnel exit

## Ground Support System Characteristics:

1. Transportation facilities
  - a. Runway/Heliport - for landing flight vehicles, for supply and emergency craft
  - b. Rail - local spur to site with connection to a main line.
  - c. Surface roads - local and with connection to state, federal or interstate high ways
  - d. Support facilities for vehicles, vehicle maintenance, and road surfaces
  - e. local pipelines for fuels and other fluids/gases
  
2. Storage facilities and environmental (weather, etc.) protection facilities
  - a. Underground fuel tanks segregated for each fuel type
  - b. Above-ground storage facilities for fuel and fuel handling
  - c. Pipelines or other transportation to flight vehicle processing facilities
  - d. Hangers for flight vehicles and MagLifter sleds
  - e. Sheds for support vehicles, aircraft, etc.
  - f. Repair shops
  - g. Spare parts and component storage
  
3. Power generation and storage:
  - a. Type - wind, solar, power grid, combination, etc. Depends on location and other factors.
  - b. Storage - capacitors, fly wheels, etc.
  - c. Quantity - to be determined
  - d. Source - to be determined
  
4. Ground support equipment:
  - a. Support, repair and maintenance equipment
    - Vehicles
    - MagLifter track and tunnel
    - Operations equipment and facilities
    - Operations support, e.g., snow removal equipment, snow cats, etc.
  - b. Emergency equipment
    - Flight equipment (helicopters)
    - Medical (ambulances and emergency medical)
    - Fire fighting equipment
    - Other
  
5. Operations buildings
  
6. Personnel habitation facilities:
  - a. Housing for permanent personnel
  - b. Recreational facilities
  - c. Emergency/Medical facilities
  - d. Educational facilities, if no town nearby

## **Task 1.1 - Initial Site Selection Criteria**

Based on the foregoing specifications of required facilities for MagLifter, site criteria are presented in the following sections. Criteria are developed for several physical site attributes: geology, geography, topography, climate and weather, transportation, power, and proximity to support services.

### **Geology of the Mountain Launch Site:**

Geological stability for the track and support facilities is the critical criterion for the MagLifter site. To insure stability, the site should have the following positive and negative attributes.

1. The country rock (subsoil rock or bedrock) should be "crystalline:" igneous or metamorphic, preferably granite or granodiorite or their metamorphic equivalents, for maximum competency. If sedimentary, thick limestone, dolomite or competent sandstone might be suitable.

2. The formations on which the track is built must be massive and uniform in composition, mineralogy, texture, mechanical strength and weatherability to sustain static and dynamic loads: weight, vibration and seismic activity.

3. If the country rock is sedimentary, the foundation bed should have thickness of at least 100 feet below the track of uniformly competent and mechanically strong rock.

4. There should be minimal crossing of lithologic boundaries along the length of the track.

5. There must be no shales, mudstones or similar incompetent beds immediately below the track site to jeopardize track stability. If bedrock is sedimentary, there must be no significant amounts of clay minerals, particularly smectites and/or illite-smectites or other clays in the bedrock to cause instability. Acceptable depths below the track for shales will depend on strength and water saturation properties of the shales or other materials.

6. There must be minimal fractures and faults in the bedrock. Fractures and faults represent rock weakness and become conduits for weathering. Weathering produces clays or dissolution, leading to incompetency. Fractures, which are nearly always present, should have their main direction parallel to the track if possible.

7. The bedrock at the rail site should have minimal weathering at depth and show no evidence of current hydrothermal activity. Weathered and hydrothermally altered material has low mechanical strength and competency. Acceptable weathering depth depends on location and distance from the track.

8. The bedrock must be stable. There should be no seismic activity (earthquakes) in the area greater than "4" on the Richter scale. There should be no volcanic activity in close proximity, nor significant explosive, ash-producing, volcanic activity in the direction of the prevailing wind.

9. Surface stability of the bedrock demands that there be no talus slopes and particularly no talus slopes with intercalated clay-rich beds (shales or mudstones) anywhere near the track, and that there be no transmission of track vibration to the ground facilities, especially fuel pipelines and power transmission and storage systems, which must be buried below frostline (about 6 feet deep).

10. Ground water should be a minimum, especially if one or more shafts and/or tunnels must be bored.

11. The "cut" for the track must go into bedrock (below the C and into the D soil horizon).

### **Topography of the Mountain Launch Site:**

The topography of the mountain chosen as the launch site is as important as the bedrock geology in defining a suitable site for MagLifter. The following define criteria for the topography of the mountain site for MagLifter. It is clear from the topographic criteria listed below that the mountain chosen as the launch site should be as isolated as possible from other mountain neighbors and surrounded by flat or nearly flat land.

1. The topography on the north, track side of the mountain must have an incline of at least 45° at the top of the slope where the MagLifter sled exits the tunnel.

2. There must be at least relief (mountain base to crest) of 4000 to 5000 feet to attain 600 mph tunnel exit speed. Part of the relief could be attained with a shaft below grade.

3. There should be a piedmont of about 1.5 miles long of 3 to 5 degrees positive slope toward the foot of the mountain for the initial acceleration of the vehicle.

4. There should be a gradual transition from piedmont through the final incline for uniform acceleration of the vehicle.

5. The track must be located on the north face of the mountain for a south or southeast launch to accommodate a Mid-CONUS launch to attain the orbits previously defined.

6. The crest of the mountain should have a long flat or a gentle down-slope about 1.5 miles long to continue the track for deceleration of the sled after launching the flight vehicle. However, the sled could veer in direction to right or left of launch trajectory.

7. There should be a wide flat area on the post-launch trajectory for emergency abort of the flight vehicle.

8. Topography at the top of mountain should allow exit of vehicle below the top to minimize effect of winds on the crest.

9. There must be sufficient flat land near the launch mountain for a runway for normal and certain emergency landings of the launch vehicle and aircraft landings.

### **Ground System Topography:**

The MagLifter site must have specific characteristics for the ground support system. Those topographic features and distances from the launch tunnel depend on final configuration and composition of elements of the ground system and operational scenario. Initial criteria are as follows. Additional criteria will be developed as the ground system definition evolves.

1. There must be contiguous flat areas for support system facilities, including flight vehicle processing, and vehicle, equipment, fuels and other storage within an easily transportable distance to the launch tunnel entrance.

2. There must be flat to gradual inclines for power systems: power generation and storage facilities and for the interface with the power grid. This area may be several miles from the launch site.

3. There must be a flat area for one or more runways properly oriented with the prevailing wind directions: generally W-NW in winter, W-SW in summer. These runways must serve the MagLifter flight vehicle, support, supply, and emergency aircraft (fixed wing and rotor).

4. There must be sufficient accessible area for emergency support facilities. These facilities will be at the launch site, at normal runways, and down range at the emergency abort landing site.

### **Mountain Environment:**

There are certain criteria that the environment must sustain for normal and emergency contingencies:

1. The top of the launch-site mountain should be above tree line to prevent fires from the flames from the rocket engines during normal launches and emergency-aborted operations.

2. Down range (the distance to be determined), in the direction of the launch trajectory, the land should be bare of trees and forests to prevent forest fires in case of emergency-aborted flights.

3. The area used for fuel and power storage should be free of trees to limit accidental fires.

4. Wetlands at the base of mountains should be minimal in area to avoid costly construction and maintenance costs.

5. Landslide- and snowslide-prevalent areas must be avoided.

### **Weather and Climate:**

Although weather and climate extremes should be avoided, almost all mountain environments with sufficient height, relief, and other attributes to satisfy launch criteria will have some extremes in wind, temperature, cloud, and precipitation conditions. The following are desirable criteria:

1. Wind - the site with the least wind will be preferred, otherwise note the following:
  - a. Surface to 20,000 feet - consistent wind direction during extended periods during the 24 hour day. The ideal site would have no wind during launch periods.
  - b. Launch site should avoid the jet stream for most polar launches.
  - c. Equatorial launches - Use jet stream to "hitch a ride" when possible; otherwise, the site should be chosen to avoid the jet stream as much as possible.
  - d. High altitude trade winds and jet stream - Use when possible, but avoid if possible. They are favorable in Northern Colorado, Wyoming and Montana in the summer, and favorable in New Mexico and Southern Colorado in the winter.
  
2. Temperature - the site with the least temperature variation will be the preferred site, specifically,
  - a. Diurnal and seasonal variations in temperature should be minimal to reduce the cost of protecting flight vehicles, the MagLifter tunnel, fuel storage and other facilities.
  - b. Moderate temperatures from mountain base to crest are desirable.
  
3. Climate - the site with moderate temperatures, but low precipitation will be preferred.
  - a. A dry climate site is most desirable to lessen ground and surface water problems and environmental dangers.
  - b. A dry climate (<10 " of annual precipitation) also has the advantage of lower population density in the immediate area and down range.
  - c. Moderate annual temperatures are desirable to reduce costs of construction, operation, and maintenance.
  - d. Moderate temperatures are most desirable for personnel working environments.
  
4. Other factors -
  - a. Factors such as rain, snow, ice, frost heave, etc., at mountain top or base should not present problems in dry climates, but could present significant problems at the mountain side, where there may be the potential for landslides and at the mountain base, where there tend to be wetlands, even in dry climates.
  - b. Areas with torrential rains that spawn landslides should be avoided.

### **Transportation and Power:**

Accessibility and transportation to and from the site is critical. Mountain sites are frequently inaccessible, except by narrow, expensive and dangerous roads. The MagLifter site must be more easily accessible by multiple forms of transportation than the average mountain site. The need for roadway and air transportation access to the site is obvious. For environmental reasons, rail access is necessary to deliver hazardous fuels and flight vehicles to the site, as well as to deliver other materials. The following represent criteria for transportation access and facilities:

1. The site must allow rail access to the site for delivery and/or removal of vehicles, materials, and fuel: access to a major route should be less than 10 miles from the site, with a spur line to the site.

2. The site must allow rail access within the site to convey flight vehicles and materials locally to support launch.

3. The site must allow access to major state, federal or interstate highways within about 30 miles, and if possible, within 10 miles.

4. The road to the site from the trunk road must be over terrain allowing transport of heavy and large tractor/trailer vehicles without excess danger to transporters or to the environment.

5. The site must allow easily useable roads within the site.

6. The site must support sufficient aviation facilities within a few miles of the launch site for landing of flight vehicles, transportation of personnel and materials to and from the site, and for emergency use.

a. The facilities must support fixed wing and rotor aircraft for normal and emergency use.

b. The site must allow a sufficient runway, depending on flight vehicle configuration and mode of flight, to allow normal landings of the flight vehicles.

c. The aviation facilities must have reasonable weather conditions all year.

7. MagLifter requires large amounts of electrical power for a short periods of time and more normal amounts of electrical power, corresponding to that of a remote mining operation. The site therefore requires the following:

a. The site must have major access to the power grid within a few miles of the site.

b. The site must be able to host, within close proximity, massive electrical storage, either mechanical or capacitance.

c. The site may need, within close proximity, its own power generating capability. If it has its own power generation, the grid must be available to accept excess power.

### **Human Population and Culture:**

The mountain MagLifter site will of necessity and desireability be remote from populated areas. However, the site must be located to provide access to the cultural, social, educational, and life-sustaining necessities for the personnel working at the site. Frequently in the Western U. S., towns are 100 miles apart. It is common for workers to commute from the towns 50 miles to their work, as miners have done for many years. It is anticipated that many or most personnel and their families would live in towns away from the MagLifter site. However, some personnel must live at or near the site. For the site residents and those who commute from towns, the following are essential:

1. There must be access by ground transportation (bus or car), to one or more towns with shopping, entertainment/recreation, and schools within 45-50 minutes.
2. There must be access to emergency medical facilities by air within 50 to 60 minutes.
3. The site environs must support at least limited personnel housing, communication for education and entertainment, possible limited schooling, and stores and cafes. This local population center must be within a few miles of the launch site.

## Conclusions

The criteria for a MagLifter site as outlined above are reasonably strict, and will eliminate certain areas and mountains inside and outside of CONUS. For example, the criteria will probably eliminate sites such as the Andes of Equador, the Coast Ranges of California, Oregon, and Washington because of earthquakes, volcanic activity, and other factors.

With the resonably strict criteria, it is probable that there will be no more than 10 to 15 sites in the U. S. that can meet most of the criteria. There are those criteria that cannot be compromised, such as many of the geologic criteria and some of the topographic criteria. However, for criteria, such as those having to do with weather and climate, tradeoffs are possible.

Some criteria have feasible alternatives. For example, for a mountain with relatively low relief, shafts could be bored to extend the length of the MagLifter track to give the proper acceleration to the flight vehicle, or to increase the angle of the track.

This preliminary specification of site criteria for MagLifter omits some specific criteria. Some of the important criteria are those having to do with specific, down-range safety factors for both human and environmental safety. These specific criteria will depend on the type of flight vehicles and the character of the flight, which are not now known.

In defining site criteria, it is clear that the site, MagLifter, and the flight vehicle will be mated to each other. The criteria established in this report are primarily those to provide a site to launch a fixed wing, aerodynamic vehicle. However, when the criteria are considered together, other vehicle configurations could make the total MagLifter concept more feasible, more efficient, less expensive, and safer, at the same time increasing site and other options. For example, a flight vehicle concept similar to the DSX, using MagLifter for launch, would add capability and flexibility to the DSX concept, while reducing the cost per pound of payload, and significantly reducing the cost of the MagLifter facility. Such a concept would reduce the size and shape of the MagLifter tunnel from large elliptical size to a smaller more nearly circular size, reduce the space and cost of normal and emergency landing facilities, reduce hazards down range, increase the angle of launch, and increase the quality of the site. The next phase of this study should consider sites with other vehicle concepts in mind.

Finally, when the preliminary siting criteria are taken together, The MagLifter concept not only appears feasible, but economically sound, with the right flight vehicle.

## **Appendix - Phases of the Site Selection Process**

The following are the research phases to choose physical, geological and geographic sites suitable for launching single-stage space vehicles into equatorial and/or polar earth orbits. This report represents Tasks 1.A, the early research of the multi-phase project to locate and characterize suitable launch sites. Phase 1 tasks are to be accomplished as part of the MagLifter site Selections, Constructability Analysis, and Implementation Strategies Study. Phases 2 - 4 will be performed as future studies. Only the portions of Phases 1 - 4 related to site selection are documented below.

**Phase 1** - The following specific tasks constitute the preliminary site identification phase.

**Task 1.1 - Preliminary Site Criteria:** Meeting with NASA and others, followed by a written report to establish technical criteria for choosing a MagLifter launch site for launching single stage ballistic and/or aerodynamic vehicles for both prototype and full-scale operation. The meeting and report shall include establishing criteria for potential orbits, launch directions, trajectories, launch safety, vehicle maneuverability, and structural strength for launch under various physical conditions, etc. Other criteria to establish are down-range factors, launch site access, on-site facilities.

Estimated time required: 10 days.

Participants: NASA, Geologist and Principal Investigator (PI: M. Slaughter), Systems Engineer and Co-Principle Investigator (CPI: P. Burke), and others.

**Deliverables for Task 1.1:** Written report documenting preliminary criteria for choosing a MagLifter flight vehicle mountain launch site.

**Task 1.2 - Map Study Site Selection:** In conjunction with criteria specified in the report from Task 1.A (this report), identify through office and library research, approximately 10-15 mountain sites in the United States and selected sites outside the U.S., potentially suitable for single stage launch sites for prototype and full-scale vehicles. Base identification on criteria established above: feasible trajectories, topography, geology, seismic activity, geography, overflight safety, preliminary geological tunneling and excavation feasibility, environmental feasibility, weather and climate, access. Prepare report for Task 1.B for NASA.

Time required: 5 months

Participants: PI, CPI and Colorado School of Mines (CSM) tunneling/excavation expert consultant.

Travel required: PI, local travel in Denver and Boulder, CO area

**Deliverables for Task 1.2:** Report with maps and recommendations for the next phase of site investigation. The report shall contain maps and advantages and disadvantages of each site selected, with recommendations for follow-up studies. The report shall also list and give reasons to eliminate other sites.

**Phase 2** - This phase will select among the preliminarily chosen sites for further study and on-site reconnaissance.

**Task 2.1 - Site Selection for Feasibility Study:** In conjunction with NASA and others, choose approximately 5 or 6 sites for reconnaissance field feasibility study from the 10-15 potential sites selected during Phase 1

Estimated time required: 10 days

Participants: PI, CPI, and tunneling/excavation expert, NASA personnel

Travel required: PI, CPI and tunneling expert to NASA

**Deliverables for Task 2.1:** Written report documenting selection of Phase 2 sites for choosing a MagLifter flight vehicle mountain launch site.

**Task 2.2 - Site Reconnaissance :** Add to the library/office studies of the 5 or 6 selected sites chosen from the selection of Task 2.2. Plan site visits to each of the selected sites. Reconnoiter each of the sites to verify, add to, and update the preliminary data. At each site spend approximately one week's reconnaissance of the site and environs. Prepare report for Task 2.2, updating preliminary Task 2.1 report.

Estimated time required: 6 months

Participants: PI, CPI, geological field assistant, tunnel/excavation expert consultant

Travel required: Subsistence and travel expenses for PI and field assistant for ten weeks and tunneling expert for 3 weeks, local travel in Denver area

**Deliverables for Task 2.2:** Report with maps and recommendations for the next phase of site investigation. The report shall contain maps and advantages and disadvantages of each site selected, with recommendations for selection and necessary follow-up studies.

**Phase 3 - This phase reduces the number of sites to perhaps 2 or 3 sites**

**Task 3.1** - In conjunction with NASA, choose 2 or 3 of the best sites from the 5 or 6 sites selected in the previous phase for preliminary site characterization and comprehensive feasibility study. Establish final site criteria based on all available data, including flight vehicle and site construction engineering.

Estimated time required: 30 days

Participants: PI, CPI and tunneling/excavation expert, NASA and other personnel

Travel required: Travel to NASA facility

**Deliverables of Task 3.1:** Report detailing sites chosen with rationale for choices and detailed documentation of Task 3.2 work projection and analysis.

**Task 3.2** - Preliminary site characterization. Working with final criteria established by NASA and site-investigator personnel, characterize the sites selected during Task 3.1. Base characterization on cost of feasible trajectories, topography, geology, seismic stability, other geophysics, geography, overflight safety, geological (structural and petrological) and engineering tunneling

characterization and costs, detailed environmental feasibility, detailed diurnal and seasonal weather and climate characterization, delineation of land access, ownership, acquisition and costs. Identify and describe methodology for excavation and /or boring tunnels and establishing support facilities. Consider launch vehicle exhaust management and weather protection for tunnel entrance and exit. Prepare report for Task 3.B for NASA. This task represents the preliminary characterization to select the final one or two sites. Comprehensive characterization of the final sites follows this task.

Estimated time required: one year

Participants: PI and technical staff full time, tunnel/excavation expert 1/3 time, geophysical services 1/6 time, drilling rig and crew 1/4 time, petrological laboratory services, engineering rock analysis services, construction engineer, full time.

**Deliverables for Task 3.2:** Comprehensive final report on character of final sites with recommendations

#### **Phase 4 - Final Site Characterization:**

**Task 4.1** - This task shall be a comprehensive review of sites and site selection data by NASA, assisted by PI and construction engineers, with the final selection of a site for MagLifter.

**Task 4.2** - This is the comprehensive geological, engineering, and environmental site characterization of the final selected site. This task is the major characterization and engineering testing task, with extensive drilling with coring, and extensive materials analysis and engineering studies. This phase incorporates drilling approximately every 50 to 100 feet at critical areas of the site, and detailed mapping and analysis of geologic, soil, topographic, mineral, vegetation, weather, wildlife, and other environmental features of the site and its environs.

A separate task incorporates the comprehensive demographic, economic and political and other necessary studies of the area surrounding the site.

**MagLifter IMPLEMENTATION STRATEGIES Report  
(MISR)**

**Phase 1, Task 3.1**

**November 28, 1995**

**Submitted by  
Dr. N. Beer, Program Manager  
and P. Burke, Systems Engineer**

**This report summarizes the results and initial conclusions of the MagLifter Implementation Strategies Meeting. It provides no tasking for the follow-on Implementation Planning Meeting scheduled for 20-22 March 1996.**

**Enclosures:**

**1) Transcripts and Viewgraphs**

- Session 1 - Critical Technologies & Research Issues
- Session 2 - Development & Integration
- Session 3 - Construction & Engineering
- Session 4 - Operations
- Session 5 - Implementation Plan
- Q&A Panel Session

**2) Presentation by Dr. Neville Marzwell**

**3) Meeting Summary & Conclusions**

**4) List of Participants**

## **SESSION 1: CRITICAL TECHNOLOGIES & RESEARCH ISSUES**

### **Capt. Mitchell Clapp, USAF Phillips Laboratory**

DR. BLOW: My name is Larry Blow. I'm from a small consulting firm called Strategic Insights. I have two things to say. That's my real name, and I am standing up. Now, with no further ado, we'll start off with our first panel. Capt. Mitch Clapp is going to talk about some of the issues in critical Technologies, and if we can, let's try to keep it to a half hour per session, so that we can keep on time and head towards the afternoon. If there's time and if we ask questions, that's great, but we'll try to keep everyone to a half hour timetable.

CAPT. CLAPP: Well, Gen. Beer told me to come in and sit down at that table, so I did that. I've always been very attentive to the requests of general officers and former general officers, ever since something happened to me when I was a Second Lieutenant. I had a three-hour layover in the St. Louis airport, so I bought a cup of coffee, a newspaper and a package of Oreos. Sitting down at the snack bar and there was no room, so the only open spot was across from this Marine Corps Brigadier General who had no hair, no neck and a silver star twice, so having put my stuff on the table, I was already committed to the engagement. What happened was, I had a cup of coffee here, the newspaper over here and a package of Oreos in the center. I was working on a crossword puzzle, trying not to bother the guy when I hear this crinkly-crinkly sound and I look up, and the General has opened up the Oreos, took one out and ate it without saying a word to me. Now, at airport prices, the nine bucks that a package of Oreos cost is a significant fraction of a lieutenant's pay. I didn't want the Marines to think that we Air Force Second Lieutenants were complete weenies, so I thought I would show the Marine with subtlety and finesse that they were my Oreos and not his, so I opened the opposite end of the package, pretending not to notice that the first end had seriously popped open somehow, and took an Oreo out and ate it very thoroughly. Now, the Marines are known for many qualities, but subtlety and finesse are not among them, so the General took another cookie, and this time he opened it up and licked out of the middle of the Oreo, and I didn't want to bother him or say anything, because the moment had kind of passed like, "Excuse me, sir, I couldn't help but noticing, you appear to be stealing my cookies," and not being an Academy man, I didn't go to the right class where they teach you how to deal with precisely this kind of situation. So I took another cookie myself and we all did, went through the whole package of cookies, never spoke, eyes never met except for maybe the barest instant, and there was this palpable tension in the air, and finally, and I'm writing down any old letter in the crossword puzzle, they finally announced the General's flight, so he gets up. He puts his important-looking papers back in his important-looking briefcase. He draws himself up with his full nine foot two and takes the Oreo wrapper, throws it away, brushes the crumbs off the table and leaves, and that's it. My God, this is the most embarrassing moment in my life, right here,

right now, because I let this guy intimidate me, just by physical presence, out of probably 3 or 4 percent of my base pay as a Second Lieutenant. But I felt worse about ten minutes later when they announced my flight. I picked up my coffee, drank the last of it, threw the cup away and pulled up my newspaper to reveal my Oreos. No kidding. This really happened. They said I had to have a joke, so that was my joke.

DR. BLOW: Before we start, I just have one remark, those of us we were talking earlier, I want to mention to the group, we have a court stenographer down in front, her name is Melodie, and she's trying to keep up with everything we say, so first of all, if you do ask a question of the session leaders, please identify yourself, if for no other reason than just to give your name, so we can trace the designation of the questions after the fact.

CAPT. CLAPP: And her name is Beer, B-e-e-r. Our breakout session was charged with talking about and understanding to some degree the critical technologies and issues involved with the MagLifter concept, and we had a very eclectic group of people, some folks that knew a thing or two about magneticism, some people that knew a thing or at least claimed to know a thing or two about launch vehicles, and while it might not excel in any of the technical issues, obviously not appropriate to a session of this size and duration, we did identify a few things that probably need to be considered in the Phase 1 effort that the MagLifter Research Consortium will get underway, and I'd like to talk about those.

## **BREAKOUT SESSION 1**

### **CRITICAL TECHNOLOGIES**

**WHAT IS "IT?"**

**WILL IT WORK?**

**HOW MUCH WILL IT COST?**

**HOW DO WE GET FROM HERE?**

**(...AND EMBELLISH THE CONCEPT ONCE WE GET GOING)**

First of all, we needed to identify requirements, you know, what is it? You know, what's the baseline that we're departing from? What we did is we went to the business plan, the mini business plan that was in our handouts, and decided that what we were going to focus around was the 5,000 pounds of pull or payload. Will it work? And the answer to that is, yes, but with a lot of effort, and there's a lot of disagreement about exactly how much effort and where it needs to be

applied. How much will it cost? We have, basically, no idea, but we do have some suggestions about things that will help minimize the cost and strategies to trade things against one other, and how do we get there from here and embellish the concept once we get going, and we have a few things to say on that, too, so that's what I'm going to tell you. I'll come back to this identical saga I told you already, just like they taught me sometime before the Oreo incident.

**MAGLIFTER CONSTRAINTS**

**"BIG" SCALE -- 700K #**

**APPROXIMATELY 500,000 # GLOW**

-  **MORE CHALLENGING INFRASTRUCTURE**
-  **MORE CIVIL ENGINEERING**
-  **MAYBE LEVERAGE X-33 INVESTMENT, PROGRAMMATICS**
-  **UPGRADE PATH TO BIGGER VEHICLES**

We decided that the baseline vehicle was a pure rocket plane, which was accelerated to some subsonic, but not very subsonic Mach number by the magnetically elevated device and magnetically driven device. The scale for putting the 5,000 pound payload in orbit means that the flight itself is going to weigh of the order of half a million pounds GLOW. That's weight at engine ignition, if you like. That gives you approximately 50,000 pounds plus or minus three delta v injected into your reference orbit, of which perhaps 10 percent is payload. Now, that's an interesting size for a number of reasons, but it's big because when you consider the weight of the carrier, or the trolley or the shuttle or the accelerator, whatever you call the thing the vehicle sits on, you're talking about accelerating mass of about 700,000 pounds, which has some implications for the infrastructure investment that needs to be made. It's probably more challenging, especially for the amount of power that needs to be applied to

accelerate the vehicle. There certainly is a lot more civil engineering involved, and I'm sure the civil engineering related group, the construction people will want to address that. We didn't have any person working on that in the people in our group, so we kind of punted that to you all. But there's some upsides to it, too, that's our happy faces here. One, is that the scale of this vehicle at about a half a million pounds GLOW is the approximate scale of the X-33 that is currently under development. All the contractors seem to be within that ballpark for the X-33 vehicles, and it gives us potentially an opportunity to leverage some of that investment. We talked a little bit about the technology challenges, and just taking the X-33 stock, slapping it on the sled, filling it up with liquid hydrogen and liquid oxygen and firing the thing in space, and for a lot of technical reasons, that probably won't work, but the idea is that of that scale, the material, the technologies and so forth developed for that purpose may have a lot of transferability, and the point is, that there are significant investments being made right now in the NASA program for reusable launch vehicles are germane to the vehicle side of the MagLifter flight system. Is there a question hanging out there?

MR. HENNESSEY: Yes, Mike Hennessey. You already mentioned delta v. I guess what I'm concerned about is they're starting from ground zero. They're starting from flat on the ground with the X-33. Why does your vehicle weigh the same amount theirs does?

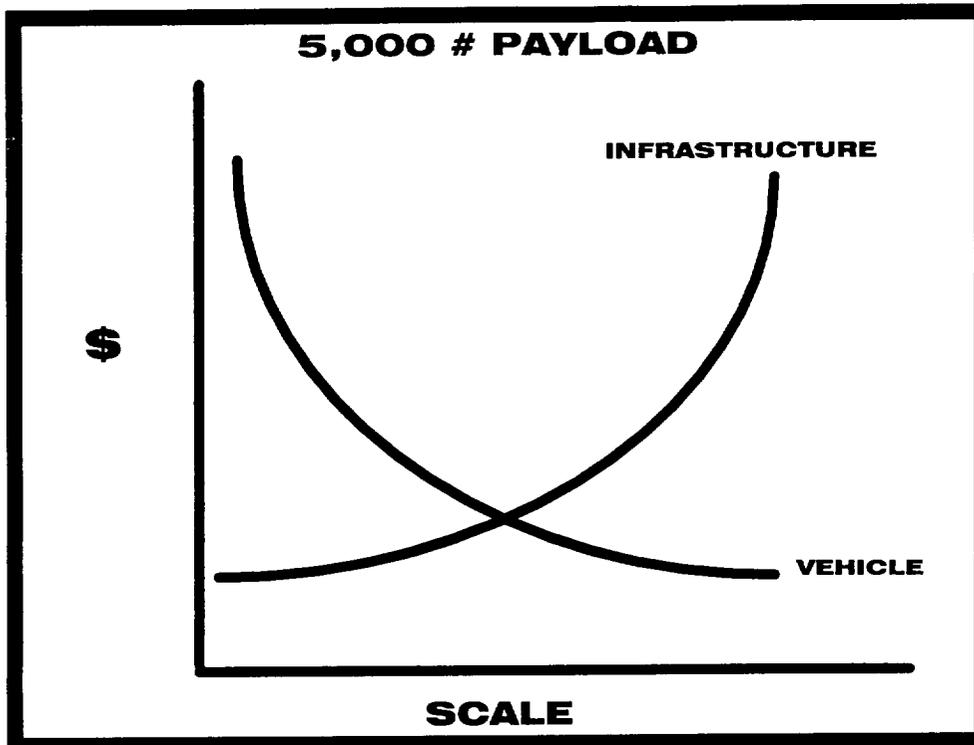
CAPT. CLAPP: Because our vehicle --

MR. HENNESSEY: Because they've got propellant and they've got a lot of vehicle weight associated with just getting to 600 miles an hour at 20,000 feet.

CAPT. CLAPP: The answer is that the X-33 vehicles are these research vehicles, which have no payload and no mission other than to accumulate knowledge, have no payload to orbit, and what MagLifter gets you is the ability to take a payloadless vehicle that maybe doesn't quite achieve orbit, and actually make a vehicle of that scale a payload-delivering machine. In other words, the payload leverage is infinite.

MR. HENNESSEY: I was mistaken. I thought the X-33 did have initial payload for orbit requirements.

CAPT. CLAPP: No, no, not at all. In fact, that's specifically restricted from the X-33, because it tends to operationalize what should be a research system. It's not X-ness, if you want to use a hideous term to describe a hideous reality.



Okay. Another thing is, that if you do bite the bullet and build something this big, then using advanced vehicle technologies gives you the potential to upgrade your half a million GLOW vehicle to a payload delivery machine for payloads greater than 5,000 pounds. Dr. Siebenhaar from Aerojet spoke at some length about rocket based combined cycle engine that offers the potential to make the payload fraction of that gross liftoff weight rise from 1 percent to perhaps 4 percent, and what that means is that with this infrastructure investment for sort of minimal conceptually simple vehicle, you have an upgrade path to a 20,000 pound payload, which is right about where John Mankins is talking about for the highly reusable space transportation scheme and the presumed economies of scale. That's the thought from his mouth that he presented yesterday, so there's potential leverage. And, again, the idea is that there are investments being made in vehicle technologies in the context of the X-33 programs and other programs that have to do with space access. That doesn't mean that you can just take an X-33 and drop it on this thing, obviously, there are technical issues that would prevent that from being a real smart thing to do. This is a little controversial, and the group doesn't entirely agree on this, but the idea is that the investment required to make the MagLifter vehicle, excuse me, the MagLifter infrastructure bigger, rises as the scale rises. If you're going to move a million pounds, it's a bigger machine. There's a lot of infrastructure. At some point the amount of power required means that you might prefer more advanced technologies for doing the power management, the energy storage and so forth,

depending on what the relative costs and investment required to get there is. To beat-up the vehicle weight to make the vehicle smaller requires, again, the application of more advanced technologies. If you have a specific payload requirement of 5,000 pounds and you want the vehicle to reduce itself in gross weight, there are advanced technologies investment required to make that happen, so at some point the investments balance between MagLifter infrastructure, the electromagnetic portion of the system on one side, and the vehicle design on the other side trade-off, and there is plausibly an optimum point, depending on the technology mix and so forth to do it, and I think that an objective of the first study that you do with your transfer of money in the MagLifter Research Consortium should be to isolate what that point is, or at least what ballpark it lies under, at least what state or continent or geographical region. Now, I'm not probably going to get to that today, but -- So here is a short list in no particular order of our conclusions.

- **O.V. HAS PAYLOAD 1 - 4 % OF GLOW**  
**NEED TO UNDERSTAND VEHICLE DESIGN**
- **MAGLIFTER - MAGDRIVER**  
**ISOLATE DIFFERENCES**
- **TECHNOLOGY FOR INFRASTRUCTURE (SCALE)**  
**INFRASTRUCTURE/VEHICLE INTERACTIONS CRITICAL**
- **PROGRAMMATIC INTERACTIONS**
- **PICK THE RIGHT SIZE**
- **SUBSYSTEM RISK MUST BE EVALUATED / DEMONSTRATED**

The first is that the orbital vehicle has payload between 1 and 4 percent of its gross lift-off or light-off weight, if you like, and we need to understand the vehicle design issues better. For example, using advanced propulsion technology may allow you to use more conventional structural technologies permitting the structural design of the vehicle to be less expensive and it could be that applying the advanced propulsion technology is a net win, that it's actually less expensive to build a 4 percent GLOW vehicle than a 1 percent GLOW vehicle, assuming the rabbit does come out of the hat on the propulsion technology. There is a distinction in the electromagnetic side of the thing between MagLifter and MagDriver. The lifting part, the suspension part is a different problem technologically speaking from the acceleration part, and there are scale effects in

that. The lift thing is relatively insensitive to scale and the drive thing begins to matter in terms of the investment requirement.

MR. CASSETTI: Isn't it more correct that it should be MagLev as opposed to MagLift?

CAPT. CLAPP: Well, you know, lift is against the gravity factor. Drive is the other direction. Again, you know, this is scroll, a piece of butcher paper, prefer whatever terminology you like, but, the point is that the suspension and the acceleration are different tasks. You use many of the same technologies to achieve them both. Obviously, we have application of high temperature, or excuse me, of high current, high magnetic fields, things like that are involved in both cases. The technology for infrastructure may be a function of scale. It's clear that you can do things with a magnetic launcher that you can't do with a magnetic railway, because of the transient nature of its operation, you can let yourself on the hook for some of the durability issues, some of the power storage issues. You don't have to run cars at 20 second headway, you can, you know, cryogenically cool aluminum composite, for example, to achieve temporary pseudo-superconductivity. It's not technically superconductivity, but it gets you the same kind of magnetic effects over a short span of time possibly sufficient to perform the mission. So there are infrastructure and vehicle interactions that are critical, and that needs to be studied. You can't isolate the vehicle from the MagLifter electromagnetic system, and that's an important point. And finally, or semi-finally, there are programmatic interactions, and this is part of the external, nontechnical context of the whole debate. Clearly, there are applications to high speed rail transport, medical imaging technology, the existence of the X-33 program, the leveraged vehicle investment, you know, in a perfectly neutral world, it's not clear what the mix of investment on the vehicle side versus the MagLifter side itself, the electromagnetic side is, but given that investments are already being made in vehicle technologies, it allows you to maybe concentrate resources to some degree on the magnetic suspension side of things.

Pick the right size. You can do an advanced technology vehicle that perhaps only weighs as much as 200,000 pounds with the carrier device that moves down the track, but if you do that, you may be at the end of the road, and have to do an entirely new track and infrastructure investment to support a 20,000 payload mission if that materializes, so understanding the market is a key point. And there is risk in all of the subsystems involved with this, and these need to be evaluated and to some degree demonstrated, experimental in an X-like program to isolate and identify what the technological risks are with all these things. That, I believe, is everything I had to say. We talked about what it was. We talked about the various techniques to make it work. The raft of capabilities that can help. I have some packages that people in our group briefed that I can pass on to you that you can incorporate into the proceedings, and we don't really know how much it will cost, but we know to start that some of the right questions to

ask, to start finding out how much it will cost and who in the external world can help, especially in terms of vehicle investment, and we need to study how to get there from here. We need to do more study. Okay. That's all I have to say with my chairman of the breakout session hat on. Please, feel free to ask any questions and members of the group, please feel free to dissent from anything I've just said, because we were by no means of one mind about this. I don't want to unfairly present just one guy's opinion, or be misleading.

COL. KIRKPATRICK: Your last point was about demonstrating capability, and you talked about the test program. Did you discuss where you would do it and how you would do it?

CAPT. CLAPP: No, we didn't get into that level of detail about how to set out the scope of the right test program. It seems -- I think there was a sense among some of the members of the group, that a lot of the technological interaction issues that I spoke of in earlier conclusions needed to be settled before you can intelligently scope a test program. That wasn't explicitly stated, I think I kind of saw that flop over people's heads.

LT. COL. JOSLIN: Randy Joslin here for the Space Command. Did you talk about the mix of technology investment, government versus -- I know you indicated that you didn't really know how much it would cost, but in terms of just focusing on technologies, not the whole program, but the technology investments, is there a right mix of Air Force, NASA and private industry technologies investment in those critical technologies that you discussed?

CAPT. CLAPP: We were having a hard enough time deciding what the critical technologies were, and so, no, to answer your question, we did not address the relevant balance between government and private and NASA investment at this phase.

DR. BEER: Okay. Mitch, we have a four and a half year time line in the mini-business plan, and our godfather, John Mankins, says that's a very fast-paced program. In order to make it a 'slow-paced' four and a half years, we need soon, like now, to pick a final configuration of what MagLifter will look like. We need to freeze it. Determine the configuration and freeze it, and accept no changes to it until after the year 2,000. If that were the charter of your breakout group, that is, to select a configuration to keep it simple, to take advantage of the technologies available and so on, if that had been what you were asked to do for that two and a half hours, could you have gotten there?

CAPT. CLAPP: I don't know, sir. I think that we probably would have, based on my sense of the discussion that went around the room, come up with something like the baseline that I briefed, which is to say, a pure rocket vehicle with approximately half a million pounds of gross light-off weight that adds 5,000

pounds to load orbit and payload ample for Teledesic, as described in your business plan, requiring certain trades to be made in terms of the electromagnetic technologies required to accelerate that thing, and just bite-off the investment needed to make that happen. At the same time, though, in a well-run program like that, you'd probably want to have some technologies investment on the side to do things like look at alternative vehicle technologies to improve and augment and embellish the fundamental quality of the vehicle, increase its payload and so forth. But if you get 500,000 pounds moving down the sled, you can do an awful lot, and that's fairly difficult to do, but that's probably a factor of five larger than what the people with the magnetic lifter training experience regard as state of the art. Is that it, approximately, right, a factor of 5X?

DR. BEER: That's not far off.

CAPT. CLAPP: Okay. So there's a bit of a leap there, you know, it's not 2X in magnitude. Anything else? Well, thank you very much, and I have nothing more to say.

DR. BLOW: Thank you, Mitch.





## SESSION 2: DEVELOPMENT & INTEGRATION

Chair: Joe Haney, Rockwell

DR. BLOW: The next session will be led by Joe Haney from Rockwell, and he's going to be talking about some of the development and integration issues.

MR. HANEY: What we looked at was that we've got to now build this thing within schedule and the cost. Do we think we can do that? I'm not going to tell you the answer yet, but I'm going to put up a couple of charts just to set the stage that I did with the group, and I'm not going to go through all the agonizing processing, but there is a process that we would have to go through to develop an integrated system.

### **DEVELOPMENT ISSUES**

- **MARKET: DRIVING SCHEDULE & RISK**
- **PROTOTYPE: OBJECTIVES**
- **SYSTEM REQUIREMENTS: YET TO BE DEFINED**
- **TUNNEL: SCHEDULE, MAINTENANCE, LOCATION, GROWTH**
- **FLIGHT VEHICLE DEVELOPMENT: SYSTEM INTEGRATION & COST**

And we looked at that and we got hung up on a couple of things. The first being who is the user and what are the requirements? And I'm going to talk about that a little bit more, and how we think that's driving schedule and risk. Requirements definition, what are they, and in that case there were a lot of TBDs. What are you going to build to? Scheduling and milestones, we didn't really touch on. Design options and trade, we talked about a few of those. Now I'll come back to those. Technology assessment was just discussed, but ostensibly to meet the schedule the technology has to exist today to meet the schedule in the business plan. Then developing the design, how do you reduce the risk, and then we talked quite a bit about the prototype system. One of the things that I struggled with and the group struggled with is if you look at the systems, and really there

are four basic systems as a part of the overall infrastructure, but just to put up the guideway, the issues associated with the guideway, what's the guideway look like? What's its shape? How long is it? How wide is it? How high is it? How is it made? What materials? How's it fabricated? How is it installed? What's the propulsion concept? What's the magnetic levitation concept? All of those things you've got to establish in the beginning so that you can then go and try to cost the system and put the system together. Whatever you do, this system has to be integrated, you know, the guideway, the carrier vehicle, the launch vehicle and the power system all have to be integrated. It's not going to be the optimum guideway with the optimum carrier vehicle with the optimum power system, and so, therefore, because it's a systems integration task, it may require a little longer time than is currently in the scheduling.

#### **MARKET**

- **ONE NEAR TERM CUSTOMER DRIVES PROGRAM SCHEDULE & RISK**
- **CUSTOMER WANTS RELIABILITY AS WELL AS LOW COST!**
- **WILL CUSTOMER PUT 100% OF BUSINESS IN ONE SYSTEM?**
- **DOES THIS DRIVE TWO LAUNCH SYSTEMS?**
- **IS THERE BENEFIT IN ADDRESSING NON-LAUNCH TECHNOLOGY?**
- **ADDRESS POST RLV TARGETS**
- **PAYLOAD COMPATABILITY WITH OTHER SYSTEMS**

The first activity that we really looked at was trying to look at the user, and what we thought that was doing to the development and integration, and this may not be correct, but this is our perception of what the reality is. It appears that the schedule is being driven by the main user, which in this case is Teledesic. If you look at the model, and when we do that, that drives the overall program schedule, and by driving the schedule, compressing the schedule, that drives the risk, and so if we add risk into it, then we go to the user and he says, "Gee, I don't know if I want this system. It's got a lot of risk in it," I have to look at alternative launch approaches. Would you get 100 percent, or would you get a high percentage of his business if he thought you were a high risk system? And so then that drove us to ask if we need two launch systems? One of the things that the user wants is low cost and high reliability. Do we have to have two

launch systems, or how do we demonstrate to the user that we are a low-cost, reliable, risk-free or an appropriate risk-taking system? The other idea that we came up with is maybe we need another user, who is a nonlaunch user. Maybe the technology that's coming out of this, especially when we get the financing, would be supported by other users of the MagLift technology. And when we looked at that, we came to the sort of conclusion, I guess you would say, that asks are we being, by addressing a very near term market, are we creating a risk in the system that would cause that near term customer not to want our system? And so that was a predicament that we were in. So one of the alternatives would be maybe we would look at a further downstream user to do that. The other thing is because we're going to be in most people's eyes, a near term or a high-risk system, we can't impose any payload requirements that are going to be unique to our system, because if they want to have a backup system, they don't want to design a payload that only works on this system, but works on a number of systems, so we're going to have to in doing this, make our system compatible with other launch systems relative to payload interfaces. We looked at the schedule in the first six months and due to the feasibility or hopefully out of the feasibility would come some of the requirements, and some of the approaches and maybe some of the trade studies.

#### **PROTOTYPE SYSTEM**

- **REQUIREMENTS FOR PROTOTYPE**
- **TECH DEMO vs VALUE-ADDED OPS SYSTEM**
- **COST, SCHEDULE, RISK**
- **"SCALABILITY"**
- **DEMO "FORCING FUNCTIONS"**
- **WHAT IS THE DRIVER?**

What we looked at next was the prototype system, which in the business plan is about a year long, and if we look at that, the first questions that we came up with are, what are the requirements for the prototype system? Normally your prototype system is to help you over some of the risk reductions and allow you some understanding before you go to the full system, but as far as what those requirements are for the prototype, we didn't have all the answers and we don't think those have been really resolved yet, and what it really got into is whether the purpose of the prototype system to demonstrate technology. In other words, what are the critical technologies in a MagLifter? Is it demonstrating magnetic

levitation? Is it demonstrating magnetic propulsion? Is it linking those together with a carrier vehicle and showing you moving it down the track? Is it getting to a certain speed? Is it being able to separate from that carrier vehicle? And what are all those technology things, or do you want to combine all of those into a prototype system that provides added value, so that when you're all done you say, hey, we've got this prototype system and guess what it does? It puts very small payloads, 50 pound payloads or so into low earth orbit, and therefore, here's a benefit you got from the prototype. Now here's an operational use, which I'll come to later, what that really impacts. But if you look at that, if you look at designing, fabricating and installing and testing a prototype system, that is a system, I don't believe that can be done in one year regardless of the dollar amount. I just don't believe that can be done. The other issues are scalability. If this is a 700,000 pound or 500,000 pound vehicle, how small can a prototype be to demonstrate the technologies for that system? And I think I've already covered the forcing function, but what's the driver? What's the success criteria from the demonstrator? What that resulted in is if you're looking at a system that demonstrates technology, that would be maybe one location. In other words, maybe I could do that at Holloman. Maybe I could do all the levitation, propulsion and maybe even separation in putting a system into White Sands into the 60 or 70 miles that you've got there. However, if I'm going with a system that develops into a mini maybe money-making system, then I get to another location. I probably can't put that there, because we were thinking about, well, maybe what you do is you use a solid rocket, well, I'm going to have stages that fall off. I probably don't want those falling on Albuquerque or El Paso, whichever way I go, and so that says maybe I can't put it in the southwest, maybe I have to put it on the Coast, and we were all voting for Hawaii. We were looking for a tour of duty there. We figured that probably would work, maybe with an increase in pay to cover the added costs.

## **RESULT**

- **DEMO LOCATION**
  - **PARTS vs TOTAL SYSTEM**
  - **COST, SCHEDULE**
  - **WHO & WHY FUND DEMO**
- DEMO vs SYSTEM FINANCING MAY BE DIFFERENT**

Then we got down to that part versus a total system test. The other part would be a prototype that maybe was a different funding agency than the overall

system, or maybe we can get an additional funding source to fund this prototype demo, because it may have added values to a whole wide-range of magnetic levitations as opposed to just the orbital system.

### **WHAT TO DEMO?**

- **TUNNEL vs NOT**
- **DESIGN, SCHEDULE, COST**
- **COMPONENT vs SYSTEM**
- **USES OF PROTOTYPE**
- **SUCCESS CRITERIA**

One of the other issues, or some of the things that came up is, what do you need to demo? If you're going to have a tunnel, do you need to demonstrate that in the prototype system? Obviously, you don't need to demonstrate that you could build a tunnel, but do you need to demonstrate that this vehicle goes through the tunnel with all the aerodynamic forces and so forth, and that really gets into the schedule, the cost issues. We personally were against a tunnel through a mountain, and I'll cover that in a little bit. When you do a demo or prototype, you want to declare success, and so part of that would be setting that prototype up so that it was successful. It wasn't something that you didn't have a chance in achieving and that got back to scheduling cost. We looked at a number of -- trying to understand, we did not resolve any issues, raised issues.

### **SYSTEM REQUIREMENTS**

- **DESIGN LIFE**
- **PAYLOAD**
- **EVOLUTIONARY vs REVOLUTIONARY**
- **RMA**
- **FAILURE ISSUES: BACKUP APPROACH**

And relative to systems requirements, one of the issues in developing and designing something is what's the life? How long should this survive? Should

the guideway be designed for 20 years, ten years, 50 years, and how much reusability do you want to put in the system? We chose the 5,000 pound payload, that was in the business spec, but then there's a lot of other requirements that go with that. Payload, that would drive the design. We didn't know, and this would need to be defined. The other approach would be, do we want this to be, obviously, a magnetic lift system is revolutionary, but do you want to, in the context of developing the MagLev system, make something that's evolutionary, that allows you to grow with time, and so maybe you don't start off with it. Maybe you find out a way to do it under 700,000 pounds, allow us to grow into that. If you do that, then it says you've got to build the guideway in the ultimate case, so maybe the vehicle doesn't get there. We've got to consider reliability, maintainability, availability of all the parts, and we just were unable to address that, and then what -- you know, you may have a failure with any new system, and so what's the backup approach? And that got us into thinking, if you got this in a tunnel and it fails in a tunnel, what does that mean? One of the most likely scenarios for failure is because it's magnetically levitated, you're going high speed and you've got small gaps. What happens if you kiss the side of the guideway? What does that do to you, or should you design to be able to do that at certain speeds, and because you have to have a backup approach that says, do you need another launch system or what, whatever, another guideway? Sort of summarizing, but not yet to my summary, it looked like, from our opinion, that the market we chose was driving the program, and that may be just a reality of life. To get funding, you've got to pick a market or a user and force it to fit in there. But you don't want to pick something that you don't have a chance at achieving and you don't want to start off on something that you know will fail, so that was the concern and we think we need to go back and look at that and address that.

For the prototype, we need to really say what are the objectives of the prototype? What do we want to get out of that prototype system? Because the prototype is probably going to be what is the next stepping stone that gives you more funding, so we need to carefully understand the prototype. We need to get the system's requirements defined, so that you can go cost the system, size the system and make a somewhat better estimate on the scheduling of the cost. We looked at the tunnel. We sort of shied away from drilling a tunnel through the side of a mountain for a number of reasons. One, we might not meet a schedule. How fast can you tunnel at 10,000 feet or whatever you're going to tunnel? The fact that the geology, the rocks are not consistent as you go through that, and that it may be availability to get to the track, that if you did a groove in the side of the mountain and then encased that to get away from the environmental, you may have a better maintainability and operability aspect. Also, if you had a failure, maybe just blow off those panels and that would relieve the pressure as opposed to having a major explosion in the tunnel. From the overall flight vehicle development and systems integration or the whole system, we feel that we need to really go back and look at the overall schedules on that.

There are a number of trades. There's a whole series of trades that I think we need to look at from the very basic, of what should be the exit velocity? Should it be subsonic, supersonic, hypersonic? How do you trade weight versus speed and payload? Should it be a manned or unmanned system? And then that has a lot of connotations not only with the cost, but with how you build it. If we would summarize, I think the basic schedule appears to be user driven, and that tends to result in a schedule, especially the prototype schedule that appears to be too optimistic. I said once before that in that one year, you've got to design it, so that you can fabricate it, so you can install it, and so you can test it, and the best any systems have done is around two years for flight vehicles and that did not have all the system integration issues here. We need to spend some more time defining the systems requirements for the various component levels. The basic, I believe that the basic concept of MagLifter is feasible. I don't have any problem with it being an unfeasible system, but I think we need to understand what the technology readiness is and how that relates to risk and how that develops into building an overall schedule. And so, therefore, I think we need to take another look at the plan, to sit down and lay out some other schedules. We looked at the cost and we had some discussion on the cost, but I don't think we have a consensus about the cost. I do think we have a consensus on the schedules, especially the prototype being requested. And that's all I've got. Any questions? Be happy to dance around the answer. Yes?

DR. HUMBLE: Ron Humble. You said you didn't have a consensus on the cost. Did you have a consensus on the range of cost?

MR. HANEY: The reason we didn't have a consensus on the cost is we looked at it and people voiced their opinion that maybe the cost was too low, but we really didn't discuss it, so we don't have a consensus, because I just don't think we discussed it enough. Would you agree, Pam, that it was just sort of, we looked at it, people made comments but we really didn't discuss it.

MR. CASSETTI: I don't think there was anybody in our group that thought it could be done for the cost. I think we were skeptical.

MR. HANEY: The cost was very aggressive. I think you can do a prototype system. You don't need \$2 billion to do a prototype system. You may be able to do a prototype system, in fact, I would probably say you could do a prototype system for \$150 million, but you've got to pick one of the right prototype systems. \$150 million is a lot of dollars in anybody's book.

MR. RODRIGUEZ: Gary Rodriguez. If we're going to use the tunnel in some form and we want to evaluate that, does it make sense then in the prototype stage to maybe stick it inside a pipe if we don't want to go dig a tunnel for that?

MR. HANEY: Well, it gets back to scalability. How big is your prototype and do you need to -- you know, the other approach to prototype testing is, do you have to do the whole system or can you break it up into component tests and still demonstrate that? So you might be able to do the tunnel in a smaller subscale, and some of the other components would be larger scale. Is that it? Oh, I knew you had one.

DR. BEER: Neil Beer. Now, Joe, the prototype development test was 12 months, and that's fairly short, but I didn't have in mind any kind of a full-up, full-scale release, launch, separation. I really had in mind what you had on that chart, which is a technology prototype kind of demo.

MR. HANEY: Okay. But even with that, let's look at that. Let's say, what are we going to demonstrate? Definitely going to have to demonstrate magnetic levitation along with propulsion. Probably one of the critical elements is once you've got this thing zipping down a track, you've got to separate it. And so then it gets into scale, and how complex do you want to be, and how fast do you want to go with your prototype and that dictates how long your track should be. One of the things that we talked about maybe as a prototype approach, would be to take the Holloman track. It's got three legs. You take the high speed leg, which doesn't get used as much, and you put a guideway over that, because now your foundation is, you don't have to worry about developing a foundation, it's already there, it's already straight, and then all you have to do is build the carrier vehicle to go over that. You could maybe separate the, just as Holloman is doing, separate the magnetic propulsion from the levitation, and do it in certain steps or stages, but I think we really need to sit down and say, "What do we want to get out of the prototype system? What's the purpose of the prototype?" You know, if the purpose of the prototype is to go to a funding source and say, "Hey, we want you to contribute several hundred million dollars and you should give us that and have confidence that we can build this system because we've done this prototype," then that sort of puts us in the situation of saying, "If I was going to give you some money, what would I want that prototype to do?" And I think we've got to go through that thought process, and understand that and say, "Can that be done in a year?" For the prototype myself personally, I don't think that the dollar amount is in question for me. You want to give me a \$150 million, I'll go prototype something.

DR. BEER: I really don't see any need to have anything but a dummy load. It really is the magnetic levitation and propulsion and that can carry the kind of gross weights that Mitch Clapp was talking about. I mean, I think that is the prototype demo. I see nothing risky, you know, about the release from the MagLifter carrier vehicle of the booster vehicle and the light-off and so on. I mean, I hadn't even thought about the booster vehicle being available that soon. I guess we could define a candidate to put on the prototype demo, but I don't see why that would be of interest.

MR. HANEY: Well, I think, you know, even subsonic separating vehicles at high speed is going to be a challenge, because you want them to separate at the right time. Especially if you're in a tunnel, you're probably going to have the engines going before you leave the tunnel to make sure that everything is operating, so I

--

DR. BEER: That's like prototyping an operational, semi-operational system that you're describing and why would one need to go that far?

MR. HANEY: Don't really know. I mean, that's why I think we need to understand what we're getting out of the prototype. What are the requirements for the prototype? And that really drives the financial customer. You know, if you went to a bank and said, "Hey, I want you to give me this money. What's your requirement to give me that money? What do I have to demonstrate before you'll give me the money?"

DR. BEER: Right.

MR. HANEY: And we were guessing that they would want a significant demonstration. Whereas, the component stuff maybe NASA or the Air Force would be willing to fund the components. Yes?

MR. RODRIGUEZ: Gary Rodriguez again. Is it possible that this prototype might be partitioned instead of having one large \$150 million prototype, in fact, break up pieces of this and work with the MagLift part of it and Mag accelerator part of it, et cetera, as discrete, different efforts?

MR. HANEY: Yes, I think there would be component tests, sure, even if your goal was to build a full system, you're going to have component tests that tell you your prototype is going to be successful, too.

MR. RODRIGUEZ: But what I'm suggesting is that by definition, the prototype is going to be not necessarily full to ignition.

MR. HANEY: Go ahead.

MR. CASSETTI: Marlowe Cassetti. We were told in our session that MagLev and MagPush have already been developed. To go do a prototype for that really doesn't make a lot of sense, it's already been demonstrated. Putting a rocket on top of a carriage that is being pushed, levitated and pushed magnetically has not been done, and that's where we got into this thinking about demonstrating the separation of the rocket from the cradle, and then, gee, wouldn't it be nice to take maybe a separating rocket and give it enough delta v so it's got the capability of pushing something into orbit. That's kind of -- there was a thought process there, that kind of goes back to some of the testing we did on Delta Clipper

where people said, "Isn't there something that you could push off that thing to get something in orbit to do just more than take off and land?"

MR. RODRIGUEZ: But, Marlowe, wouldn't you entertain the notion that perhaps taking a 300 knot MagLift train is, you know, going to -- what we are going to do with nearly Mach 1, that is not necessarily a 2X linear process. There's probably a lot more involved in making that vertical, that it may not be as state of the art as we like to think.

MR. CASSETTI: We kind of answered that question by looking at if you've got some investors out there who want to go invest some money, we want to give them a good enough reason so that they don't go to jail, like the guy who was playing hedged bonds in Orange County, because he was being fiscally irresponsible. We want to give them enough ammunition so they won't go to jail for taking somebody's money, you know, and pushing it down a rat hole. So you've got to make a meaningful enough prototype to get people to climb on board this and feel that they're doing it with an intelligent decision.

MR. HANEY: Either your prototype has to be more complete or your development schedule has to stretch out, so that in the development schedule, you allow a prototype development process. In other words, you say, "Okay, well, I'm going to build a system now and I'm not going to go to the full velocity. I'm going to go to partial velocity. I'm going straight. Now I got to go up a mountain at an incline." You know, making that turn from level to 45 or 20 degrees magnetically levitated is going to be a challenge.

MR. TURMAN: Bob Turman from Sandia. I agree that the statement that you made earlier, that magnetic levitation has been demonstrated and magnetic acceleration has been demonstrated. The two of them together, the combination that we're seeing here, I don't think has been demonstrated. Certainly not in an engineering sense. So maybe one approach to this prototyping would be an incremental prototyping where the first thing I would do is demonstrate the MagLev for the vehicle and an acceleration of three Gs or on that order. Do that in a scale of a couple of hundred meters, that's a fairly reasonable vehicle, a fairly -- maybe a 500 kilograms or something like that, that's a fairly reasonable scale, and probably the facility, the launcher cost is like \$10 million, I would guess. If we do that first, just demonstrate that you can levitate it, you can stabilize it, you can accelerate it, that would be a big step beyond what Trans Rapid does with their teaching of their MagLev vehicles now. The next step then would be to take that vehicle, put a rocket on it, then use that same launcher with the rocket stage and use it as a suborbital, then you could use that same test facility to look at the separation issues. I would do that all outside the tunnel. If we were successful there, maybe put a big tube around it and look at the aerodynamics. That's probably three or four steps, and I don't think you could do

it all in one year. I don't think you could, but I would think that would be discussed.

UNIDENTIFIED SPEAKER: That represents a reasonable partition, because no one component, you're not looking at \$150 million reach. You're looking at incremental, ten and 20 pieces.

MR. WOODRING: Marv Woodring, General Atomics. I think just one observation, if you're going to have to advance a lot of market knowledge, engineering might be prepared to buy some of the separate tests. The people that are going to be making investments are probably bankers and accountants and people with that sort of background, risk-takers, probably. They're going to need to be convinced that what you've done is sufficiently prototypic of the system, that they're going to be willing to put up money and risk losing it, so it's not engineers we're trying to convince, it's the general public or the investment company.

MS. BURKE: Pam Burke. One of the other things that we have to remember is, we're trying to convince the people that are going to fly on it, and they're going to be very risk adverse, I would think, if you came with a new system. If the prototype or demonstrate system doesn't show them that the system is going to work and it's capable of flying them, you're not going to get passengers. So one of the things we considered in the group was, if you don't have a prototype or a demonstration that is significant enough to show the concept, proof of concept, one, you may not have a market when you're done, and if you don't have a market, you don't have funding, and so you're not going to have to bother with the prototype, because you're not going to have anything to do with it. So we do have to consider that the prototype has to be done to convince a potential market that this is a usable system and risk-free or risk-lessened.

UNIDENTIFIED SPEAKER: Another problem with having too large of a chunk is that you're putting the old eggs in the basket issue. If you have a failure, then that becomes a big issue, a big problem if it's a bigger piece.

MR. HANEY: Yes, I want to clarify one thing. I don't want to give the wrong impression, that we thought it had to be a prototype all or nothing type system, that even the prototype is somewhat evolutionary. It was just a final step of our prototype, had to be somewhat prototypically, so that people would say, like Marv said, "I don't have to say, 'Well, gee, you can test this. Here are the equations that get you from this to a full-sized vehicle,'" that they can visualize you did that. I believe this will happen, and so that was our basic process, because we don't believe our funding source is the government. We're not dealing with engineers and NASA and the Air Force, and that chain of command that's used to working that way. We're dealing with a different customer. Yes?

MR. de ROCHEMONT: Pierre de Rochemont. A point that Bob Turman brought up on technology issues, Bob, correct me here if I have misspoken, is that the Teledesic orbs involved are apparently unstable, and maybe what we should use in the business plan isn't the installation of Teledesic, but Teledesic, if those orbs are unstable, would need a highly responsive launch method to repair holes in the net as the birds drop out of orbit and maybe that's what we should gear, you know, the financial structure around, and you know, stretch out the prototyping and look at the market potentials, meaning, I guess, the recent --

MR. HANEY: Which was 60 flights a year.

UNIDENTIFIED SPEAKER: That's in the plan. Some of that's replacement.

MR. de ROCHEMONT: Maybe that's what we should look at. That way, I guess, we keep all the parties happy. Technologists feel secure with what they have developed and the user will have a higher level of comfort.

DR. BEER: I'm missing that point. Pierre, would you say that again or say it differently?

MR. de ROCHEMONT: Right now we're looking at establishing a schedule that is more aggressive than I think most people feel comfortable with. We like the prototype system. We like to have a level of assurance that we don't feel can be met in a time frame to install the Teledesic constellation, but this business potential, once Teledesic is up there and what we should be looking at in that case, since we're looking at stretching out the prototype, meaning the installation of a MagLifter or maybe a blind assist system, is trying to capture the resupply market to Teledesic rather than the installation parts. We should look at speaking with Bill Gates of Microsoft, you know, we'll need a follow-up system that will lower the maintenance cost of their net.

MR. HANEY: See, I think if the system that we set up, to do an analogy, was an X-31, you could even take the prototype step out. You say, "Okay. Now, we're going to build an experimental facility and it may or may not pay for itself, but we're demonstrating the technology, that's one stretch. But what we're trying to stretch to is an operational system, which has to have much higher reliability than a classic two year X vehicle program, three year X vehicle program.

MR. de ROCHEMONT: I guess the resupply market is going to have to be very responsive, I guess, launch in a day, less than a day.

DR. BEER: Just one quick point. Teledesic's plan is that the spares go up, you know, at the same time, so there's like four spares per orbit, that's like --

MR. de ROCHEMONT: But it may be less expensive to keep them on the ground --

MR. CASSETTI: Obviously, they can't stand the outage. They can't even stand a day delayed launch or a few days. They still I think --

DR. BEER: We put something in there for replenishment, I'm not sure what that number was, maybe we should look at that.

MS. BURKE: We also looked at not only using Teledesic. What we need to consider is a vehicle that has more than one user, so that -- and prototyping them would get us into being able to say we've got a series of users, by doing a good job of maintaining requirement by definition, that's incorporating more than just a single user driving the whole technology. That reduces the risk.

MR. HANEY: I'm getting the time hook.

DR. BLOW: Yes. Could we hold the questions?

MR. HANEY: I'm going to make one closing comment. I think what we just need to do, Neil, is go back, look at the schedules, and answer some fundamental questions, you know, what are we trying to get out of the prototype, who is the customer, and how much risk should we impose on the customer, and then see how the schedule comes out, or how much is he willing to take?





## SESSION 3: CONSTRUCTION & ENGINEERING

Chair: Ralph Christie, Merrick & Company

DR. BLOW: The next session is going to be led by Ralph Christie from Merrick. He will be talking about Construction and Engineering requirements.

MR. CHRISTIE: We're pretty much on schedule, so hopefully, the engineering and construction group can keep the project on schedule. Our assignment kind of reminds me of a story a few years back in the Mid East crisis. Gen. Schwarzkopf was kind of down and out, had a long couple of days. Walking through the desert, he comes upon this lamp. Sees this lamp and says, "What have I got to lose?" He picks up the lamp and rubs it and out comes a genie, and the genie says to Gen. Schwarzkopf, "You've got a wish. What would it be? Any wish in the world." He said, "I wish there was peace in the Mid East." She says, "I'm a pretty good genie, but that's a tough wish. How about a second wish?" "Okay. I happen to be a Denver Bronco fan, and how about the Denver Broncos win the Super Bowl?" She says, "Can we go back to that first wish?" So that is kind of what we were like. We had to step one challenge at a time, one wish at a time.

<b>ENGINEERING &amp; CONSTRUCTION PARTICIPANTS/PERSPECTIVES</b>	
<b>FIRMS</b>	<b>FOCUS</b>
<b>4 - E/As &amp; CONSTRUCTION</b>	<b>ENGINEERING/DESIGN CONSTRUCTION OPERATION INTERFACE</b>
<b>1 - GOVERNMENT</b>	<b>SYSTEMS/MARKET/ PROGRAMMATICS</b>
<b>1 - EDUCATION</b>	<b>SYSTEMS ENG &amp; FEASIBILITY SUPPORT</b>
<b>1 - MINING</b>	<b>TUNNEL/GEOLOGY</b>
<b>1 - GEOTECHNICAL/ ENVIRONMENTAL</b>	<b>GEOTECHNICAL/ ENVIRONMENTAL SITING</b>

Session 3, Engineering and Construction, just to give you a little perspective of who was in the group, because I think that was a good cross-section. We had four engineer architects or constructors represented. Their focus was the

obvious engineering design, construction and operation interface. We had one government representative. His focus was more on the systems, programmatic side, the marketing side. One from the educational community. His interest focus was systems engineering, and offered to do some facility feasibility support. One mining company, obviously, from the tunneling and geology side. We feel we had our bases covered there. One geotechnical/environmental firm addressing those issues, so I believe it was a good cross-section to be looking at the engineering and construction. We wanted to answer the following four questions:

**ANSWER THE FOLLOWING:**

- **TECHNICAL FEASIBILITY**
- **ECONOMIC FEASIBILITY**
- **PROGRAMMATIC FEASIBILITY**
- **OPEN ISSUES**

I think John Mankins said it best at end of the session this morning, we need to look at technical feasibility, economic feasibility and programmatic issues, and also any open issues and what are the next steps, so that's kind of how we approached it.

We've got two cases. These are the assumptions or the ground rules, if you will. Case one, we're going to build this thing on bedrock. Fracturing of material in rock was obviously going to be an issue, so we needed to identify an area where we can actually mount this thing in bedrock. SMES, we left that to the other group, is feasible and we assumed that it was furnished -- it's not in our cost. In a minute we're going to show you engineering and construction costs. It does not include the SMES. It includes the facilities for the SMES. Many people talked about the market, but we just went ahead and assumed there is the market to support full-scale deployment. We just said if we get wrapped up in thiemarketing discussion, we will never address our issue of what we were assigned to do. We looked at 5,000 pounds LEO for I think, John, in your case, we went back and chatted with you briefly, but I think we used the Mach II vehicle to satisfy this particular case of 5,000 pounds, because when you look at John's analysis, he's got several vehicles there, not just a Mach II, but a Mach I and a Mach III, and so forth.

**ASSUMPTIONS/GROUND RULES  
MARK II VEHICLE (MODIFIED PAYLOAD)  
CASE I**

- **BUILT ON BEDROCK**
- **SMES FEASIBLE AND FURNISHED BY OTHERS**
- **A MARKET TO SUPPORT FSD**
- **5,000 LBS LEO**
- **45 50 DEGREES INCLINATION (BALLISTIC)**
- **REUSABLE VEHICLES**
- **10 METER TUNNEL (3 METER VEHICLE)**
- **DOWN RANGE TRACKING etc. BY OTHERS**

This is the case. Case I is 45 to 50 degree inclination, the ballistic one, reusable vehicles, and a ten-meter tunnel is one of the things we talked about. The vehicle itself only needs a three-meter diameter tunnel, but because of the power systems and the maintenance around it, we got four engineers together and said, "Tell me your thoughts here." Downrange tracking, et cetera by others, we will have on-range tracking and telemetry support, but obviously siting is always a question. Depending on where you put this down-range tracking, may or may not be an issue. May be able to just utilize the Western Test Range or Eastern Test Range.

**ASSUMPTIONS/GROUND RULES  
MARK II VEHICLE (MODIFIED PAYLOAD)  
CASE II**

- **37 METER TUNNEL (30 METER VEHICLE)  
(CUT & COVER)**
- **20 DEGREE INCLINATION/AERODYNAMIC**
- **LANDING SITE ADJACENT (< 20 MILES)**

Case II is slightly different. It's a larger vehicle. It's a larger tunnel. How do we get that number? 30 meters to take care of the wing span of the vehicle, and then seven meters is the same seven meters we used before on the allowance of around the vehicle for the tunnel. 20 degree inclination. This particular vehicle is aerodynamic. We believe the landing site needs to be adjacent within 20 miles, and we put that in the cost.

## **CASES I & II**

### **TECHNICAL FEASIBILITY**

- **10 METER TUNNEL**
  - **FEASIBLE FOR BORING**
  - **ASSUME GEOLOGY IS ACCEPTABLE**
    - **IGNEOUS/METAMORPHIC**
- **HIGH MAINTENANCE ISSUES:**
  - **DEWATERING SYSTEM**
  - **WALLS MAINTAINED**
  - **CORROSION/WEATHERING**} **SOLUTIONS AVAILABLE**
- **SITING: IDENTIFY AREA LESS EARTHQUAKE PRONE**
- **LINING MATERIAL TO SATISFY:**
  - **OVERPRESSURE**
  - **ACOUSTICS**
  - **HEAT**

So this is the basis for everything we addressed on the engineering construction side. It's not rocket science as John said. We can build this, but there are some issues that need to be evaluated. We need to take a good engineering approach to it, and then go do it. Ten-meter tunnel for the first case is feasible for boring. We made the assumptions the geology is acceptable, igneous or metamorphic rock is preferable, according to our geologist, in order to get to the bedrock type of material that we want. High maintenance is something that does need to be looked at, as John indicated, but that the O&M costs cannot be ignored. We've got to look at total life cycle costs. From a construction standpoint, the best way to drive this cost down is to look at some dewatering systems, maintaining the walls looking at the weather and corrosion issues and designing walls for that. We do have a cost allowance in here for wall containment. We do have solutions available. We're not suggesting that these are issues as much as probably should have put considerations. Siting, we identify an area which is not earthquake prone. Obviously, the higher the probability of earthquake, the higher the cost, so that's a siting issue. Lining material needs to satisfy overpressure, acoustics and heating, and we thought Coors would love to look at that.

## ECONOMIC FEASIBILITY

<b>CASE I</b>	<b>SWAG" IN MILLIONS</b>
<b>ENVIRONMENTAL &amp; SITE INVESTIGATION</b>	<b>\$40</b>
<b>TUNNEL (3 MILES)</b>	<b>\$400</b>
<b>GUIDEWAY POWER</b>	<b>\$100</b>
<b>GUIDEWAY (\$15m/MILE)</b>	<b>\$50</b>
<b>TELEMETRY/ON-RANGE TRACKING</b>	<b>\$25</b>
<b>SMES FACILITY, MISSION OPS, FUELING, CHECKOUT FACILITIES, etc.</b>	<b>\$150</b>
<b>AIRDROME, FLIGHT OPS</b>	<b>\$10</b>
<b>INFRASTRUCTURE(POWER,ROADS, etc.)</b>	<b>\$50</b>
<b>LAND ACQUISITION</b>	<b>\$150</b>
	<b><u>\$1.025</u></b>
<b>CASE II</b>	
<b>(\$200 M LESS)</b>	
- <b>CUT &amp; COVER vs TUNNEL</b>	<b>\$800</b>
- <b>BUSINESS PLAN</b>	<b>\$550</b>

Economic feasibility, there has been a lot of talk about cost. We just went ahead and took a bold SWAG at it, and you'll note I said SWAG. Environmental and siting investigations, this is for the whole baby, all the way through to full-scale deployment, if you will, we put \$40 million down, \$20 million each. We felt that these two exercises could not be taken lightly. They're going to be costly. We tried to put realistic numbers down and that was input again across the board from engineering companies as well as environmental firms. The tunnel we assumed was the three-mile tunnel. This is the case, again, where we're actually going to bore a tunnel. We have got \$400 million for that. There was a recent project that was cited. We used that number on a dollar per mile basis, if you will. Guideway power, we put \$100 million. The guideway itself, \$50 million, and again, the assumption is that the down-range tracking is available. We've got some on-range stuff and telemetry, for \$25 million. Then the group of facilities that have been mentioned in some of the work that John has done, SMES facility, mission OPS, fueling facility, checkout facility and so forth, we put \$150 million allowance for that. Airdrome and flight OPS, we felt would require \$10 million. Infrastructure, which includes power, roads and other necessary utilities at \$50 million. We've got land acquisition allowance in there of \$150 million. Comes out to a nice round number of a billion dollars, slightly above. Case II would be less, because we're looking at not doing a tunnel, because of the larger configuration and the inclination, or more of the inclination, I should say, we could cut and cover versus a tunnel, that gave us \$800 million. Just for comparison, in the business plan we were more in the range of \$550 million.

MR. HANEY: Joe Haney. In your cost, your first cost estimate you just had up, where was your cost estimate for your vehicles going to deliver the payload?

MR. CHRISTIE: The vehicles are not in here. We looked at purely engineering and construction of the facility and the site. We assumed, and that may be a false assumption, that one of the other sessions was looking at vehicle architecture and the cost for the launch vehicle. Yes, sir?

MR. HAYNER: Mike Hayner. When you say airdrome particularly in dollars, what are you assuming there?

MR. CHRISTIE: The one who came up with that number was Ron.

MR. TORGERSON: That payment, probably the flight operation center, whatever kind of dynamics, probably includes the MOA or anything that's included with it.

MR. HAYNER: Not even close.

MR. TORGERSON: I don't know.

MR. HAYNER: You're talking for a recoverable vehicle, and for a recoverable vehicle -- you've got to land on a landing strip.

MR. CHRISTIE: Vertical.

MR. TORGERSON: Vertical.

MR. HAYNER: Vertical landing? DCX like powered flight.

MR. FAERY: Well, that's what the thought was for this.

MR. CHRISTIE: Again, open for discussion.

MR. FAERY: I think you need an airstrip if you're going to get payloads in and out of there.

MR. CHRISTIE: So \$50 million, \$100 million?

MR. FAERY: I have no airfield. I know they're a lot.

MR. SULLIVAN: Ron Sullivan. I have a question about the cost of the economic feasibility, seems like you should add cost of money and taxes. This is a significantly large amount of investment which is largely capital, which will remain in the state or the location. They're probably going to tax you, so that --

MR. CHRISTIE: That's a good point. There's no escalation in here. These are in today's dollars.

MR. SULLIVAN: So a return on investment for the people that are actually investing in this.

MR. CHRISTIE: Right. We talked about economic feasibility. You're absolutely correct. We only took it as far as capital cost or nonrecurring cost. We didn't look at the revenue stream. We didn't look at the amortization of costs and all those types of things. We just bloody ran out of time.

MR. SULLIVAN: Also, on your facilities, you think your launch base facility, your speed facility, mission OPS, checkout, et cetera, again, I think that's really underscoped. That may be using some alternate facility, but even so, depending on where that's going to be done, I'm assuming it's going to be done up in the mountains somewhere, you've got to establish an entire base up there.

MR. CHRISTIE: Right.

MR. SULLIVAN: And I don't think you can do that for near \$150 million.

MR. CHRISTIE: Well, to address your question or relate it to that, and I didn't probably mention it in the assumptions, we're assuming this is a commercial operated type facility.

MR. SULLIVAN: I'm still assuming you've got to put a population of people up there, you're going to have to have housing for them, some offices for them, food service, recreation.

MR. CHRISTIE: Right, trailers.

MR. SULLIVAN: And all of the things that have to go along to support an ongoing day-in and day-out mission. A lot of that, a lot of the commercial aspects of a campaign thing where you deliver a short-time, launch something and get out of there, this is a day-in and day-out operation, so you've got to build infrastructure there that's more than just a couple of hangars, so I think somebody needs to take a hard look at that.

MR. CHRISTIE: Okay.

MR. SULLIVAN: You look at our current launch bases, they're probably half a billion to billion dollar investments. A lot of that is needed for this operation. You ought to know the reason for the various facilities and someone needs to seriously sit down and look at that.

MR. CHRISTIE: One thing we looked at was the cost of some recent launch complexes that have been built, and if you pare back the MST and the launch complex itself, and look at all the support infrastructure around it, we kind of looked at it that way. That the bulk of that cost was construction of the MST and all the launch complex cost. We're talking about just the support facilities around it, and quite frankly, that is a SWAG. That is an absolute SWAG, but you're right.

MR. SULLIVAN: Again, you've got to be careful, if you SWAG low, then you're going to go over the wrong number.

MR. CHRISTIE: Well, we've increased John's number about 40 percent. Go ahead.

MR. HENNESSEY: Mike Hennessey, Intermagnetics. Did you say that the SMES was not included in the price?

MR. CHRISTIE: Right. We had a tough time costing that. We were hoping maybe that Jim Lowe or someone else could help us on the cost side of the SMES. We've got some costs in here for foundations and site preparation, but SMES itself, we believe is a big number, and no one in the room felt comfortable throwing out a number.

MR. WOODRING: Marv Woodring, General Atomics. You might want to take a look at the alternative, and other than just SMES, part of the problem on this thing, I think, is going to be power of distribution if you have one single SMES unit you're doing. The real problem getting very far away from that, you might want to look at a distributed array of motor generated or something like that, would keep you clean and they're reliable and if used, least expensive.

MR. CHRISTIE: Thank you.

DR. BEER: I have a question, Neil Beer, on tunneling cost. Is that high, \$400 million, because this is a 37-meter tunnel? This is only three miles long and Swiss metro is --

UNIDENTIFIED SPEAKER: It's a ten-meter tunnel.

MR. CHRISTIE: Yes, we used costs from a couple of different companies on our task force. They ran some numbers. They ran a lot of recent projects on a dollar per mile basis based on cubic meters removed, and then we also backed it up. We also did a sanity check for people that live in Colorado. The last 15 years they have been talking about building a tunnel under Berthoud Pass to get to Winter Park, and if you track that over the years, the last number that they have been talking about is \$350 to \$400 million, about twice that long, that they, again,

the experts in the group felt that because we were boring at an inclination and some other challenges, that they don't have at Berthoud Pass, and that's also a four year old number, \$350 million on Berthoud Pass.

DR. BEER: Is Dennis Lachel here yet?

MR. CHRISTIE: No, unfortunately Dennis wasn't in our group. He was the only one missing.

COL. KIRKPATRICK: Doug Kirkpatrick. The Operations Group thought that having one rail, one failure would shut down the whole operation could be a little extreme. We thought maybe we could make two tunnels or a double-wide tunnel. Is there any economy in scale that can be gained from doing a double-wide tunnel, having two rails through, that a failure in one tunnel doesn't shut down the whole system?

MR. CHRISTIE: Where's Maynard?

DR. SLAUGHTER: I don't know the answer to that.

COL. KIRKPATRICK: It seems to me to throw a 200,000 pound cradle, though, off of the track, the other one that --

UNIDENTIFIED SPEAKER: You wouldn't want it too close, which means two full tunnels.

COL. KIRKPATRICK: Right.

UNIDENTIFIED SPEAKER: Which sounds like twice the revenue.

MR. CHRISTIE: Good input. I know when you get into dollars, people are always interested.

## CASES I & II

PROGRAMMATICS	TIME (YEARS)	
	IND	CUM
NTP JUNE 1, 1995		
FEASIBILITY STUDY		
- TECHNICAL/ECONOMIC	0.5	0.5
- ENVIRONMENTAL (PROTOTYPE)	0.5	0.5
- SITE INVESTIGATION (PROTOTYPE)	0.5	0.5
PROTOTYPE	1.0	1.0
FULL SCALE		
ENVIRONMENTAL	2.5	2.5
SITE INVESTIGATION	2.5	2.5
DESIGN	1.5	2.5
CONSTRUCTION	2.0	5.0
CONTINGENCY	0.5	5.5

ILC

JANUARY 1, 2001

Okay. We looked at the programmatic side of this, and as far as is it feasible to build in the time we talked about and what some of the steps are, and so what we did is we broke it into, if you will, Phase 1, which is feasibility, and some of these items here and then full-scale deployment. We're going to assume a notice to proceed June 1, Neil, so take all the time you've got so long as it's only three weeks or less, a couple of weeks. We broke this into individual and cumulative, so these are estimates in years. This is a cumulative in time, and we have taken it, like I said, from the feasibility down to full scale deployment. It's obvious, you can see the tall pole in the tent according to the group, with some environmental and site investigation, two and a half years, and maybe that's a function of, again, where we zero in on, but it was recognized as one of the tall poles in the tent.

MS. BURKE: What do you consider environmental? That's not a full DIS.

MR. CHRISTIE: Record of decision, so that we can dig dirt.

MS. BURKE: But you don't have the whole five year DIS. Could you waive the whole five year DIS?

MR. CHRISTIE: I think it would be a function of where we go. That's what we wrestled with. I mean, just depending on where you build this, that time line could shrink tremendously or it could increase tremendously. But I had done a year and I got crucified, so we settled on two and a half years. The design, we looked at the design-build approach with some parallel going on between design and construction at the same time. For management reserve sake, we stuck it in

contingency. With all of that you've got the five and a half years from notice to proceed to initial launch capability of a full-scale system.

MR. CASSETTI: You're going to have that same time line, whether you've got a cut or a full tunnel it would seem.

MR. CHRISTIE: We thought it would be pretty close, Marlowe. With the conceptual nature of this whole thing, we just used the same time line, unless someone has done some homework since then. The question was, if we go to the cut-and-cover versus the boring, are we going to really save that much time? I think when we talked about this, Maynard, the parallel effort of that going-on while we're building all these peripheral facilities...?

DR. SLAUGHTER: Probably save a little bit of time, but not much.

#### **OPEN ISSUES**

- **POWER REQUIREMENTS**
- **MARKET DEFINED / VALIDATED**
- **DUAL USE**
  - **BETTER DEFINITION OF FACILITIES**
- **DO FEASIBILITY STUDY & MARKET ANALYSIS NOW!**

MR. CHRISTIE: Right. Final comments, we believe there are some open issues, more than what's probably the ones on this chart. Probably just food for thought. Power requirements side people in our group felt very uncomfortable, maybe not having the background in that area, to fully address it, but hoping that someone else would address the power requirements, making sure that the SMES was addressed technically, make sure, do we need to tie into a power grid somewhere? With the kind of numbers we were looking at, we just thought it was probably infeasible to do that. Many people brought up the market. Again in our assumptions, we just assumed the market was there. Dual use, if it's a dual use, it could drive the cost up even more. We were assuming that we were going to go to more of a commercial approach. If that's not the case, then we need better definition of facilities, and obviously, continue evaluation of the cost. "What do we do next?" Neil, you asked. We believe you need to do a feasibility study. You need to do a market analysis now, get your arms around this thing, see what we've got.

**NOT ROCKET SCIENCE, BUT MATCH SYSTEM COST TO  
MARKET**

**\*\*\***

**COURAGE TO CHANGE !!!**

And this is a comment just from a couple of us, and it's not rocket science, but we must match the system and cost to the market. My last comment is, we've got to have courage to change. We have got to have courage to change as an industry and as a country, and that's just kind of an editorial comment. So with that, I open it up for questions.

DR. FOSHA: Charles Fosha. Are there any facilities that may have some infrastructure, like a Leadville mine? I'm thinking about that, it already has the power and the facilities, was that discussed at all, like Leadville?

MR. CHRISTIE: Not a lot, really. That's a good thought. Maybe some of the infrastructure concerns that Michael has could be addressed depending on where it's sited. If we put it down south, central Colorado, there's abandoned ski areas, lots of places for people to live, lots of condos down there right now. So there are some costs we can avoid, and Colorado being a mining and agriculture state, we do have some built-in infrastructure here. That's a good thought. We assumed in the long run this thing was going to be environmentally approved. I got a little bit of resistance from it, but I just made a comment that I spent the last couple of days driving around the western states and we're putting a hole through the mountain here. I don't know the last time you've been in Montana, Wyoming and Utah, some of the big mines, but there are some big holes there, and, yeah, they were permitted a long time ago and all that, but there are some big cuts, some big mines, so we're going to assume it can be done.

DR. BEER: What are you going to do about the two-year problem? You have showing 2001.

MR. CHRISTIE: We're going to get creative and market like hell, Neil.

UNIDENTIFIED SPEAKER: Slow Teledesic then.

CAPT. CLAPP: Actually, the latest I hear from Teledesic is that they are most likely to launch in the year 2000.

LT. COL. JOSLIN: Randy Joslin. Ralph, Case I you made about a billion in investment largely in infrastructure, some of that was real estate. The expertise in the group, did you discuss how much it would cost to maintain that infrastructure on an annual basis?

MR. CHRISTIE: Not a lot other than we're real sensitive to the tunnel site, that the design and the approach could really impact cost downstream. The wall structure and the dewatering systems and everything, so we did not, if you will, estimate a percent of capital cost would be recurring cost. We didn't get into that. We didn't get into staffing, you know, how much staffing would it take to support that. We just kind of ran out of time. That's obviously an issue. John brought it up. We need to look at the whole life cycle cost of this thing to truly do an economic feasibility, because the title is somewhat of a misnomer, because what I provided you is just capital cost.

MR. TURMAN: Bob Turman. What case study were you using here? How much energy do you store in the SMES, which one were you working with?

MR. CHRISTIE: Well, it was the case study for the Mach II, whichever one that was. There's about four different scenarios that were in John's papers. Does somebody have the numbers on the energy stored? I can't remember. It was in gigawatts.

MR. TURMAN: Gigajoules is what it has here. I was wondering if we can get a rough estimate on what the SMES cost would be.

MR. CHRISTIE: Right. We felt very uncomfortable with that. Anybody willing to throw a number out? Yes?

MR. HENNESSEY: A very rough number based upon just current magnets puts it up in the billion dollar range.

MR. CHRISTIE: Okay. So that's where we've got to get creative. One more question.

DR. OBERLY: The SMES isn't the only way to store energy. That may not be a cost effective way to store energy. If we did it with rotating machinery, potentially you could do it cheaper if all of the requirements were right and still with inertial energy stores.

MR. CHRISTIE: Okay. Thank you.





## SESSION 4: OPERATIONS

Chair: Chris Chisholm, ANSER Corporation

DR. BLOW: Chris Chisholm is going to talk about some of the operations considerations that they debated. Chris?

MR. CHISHOLM: The Operations panel, we took the approach that what we would try to accomplish was identify some of the operational issues that would affect launch and system design.

### OPERATIONS PANEL

- **INLAND LAUNCH SAFETY**

- 1ST PRIORITY FOR FEASIBILITY STUDY**

- **TWO APPROACHES:**

- **RANGE LAYOUT**

- **CASUALTY EXPECTANCY ( $E_c$ )**

- **RANGE:**      $E_c = 3.0 \times 10^{-5}$

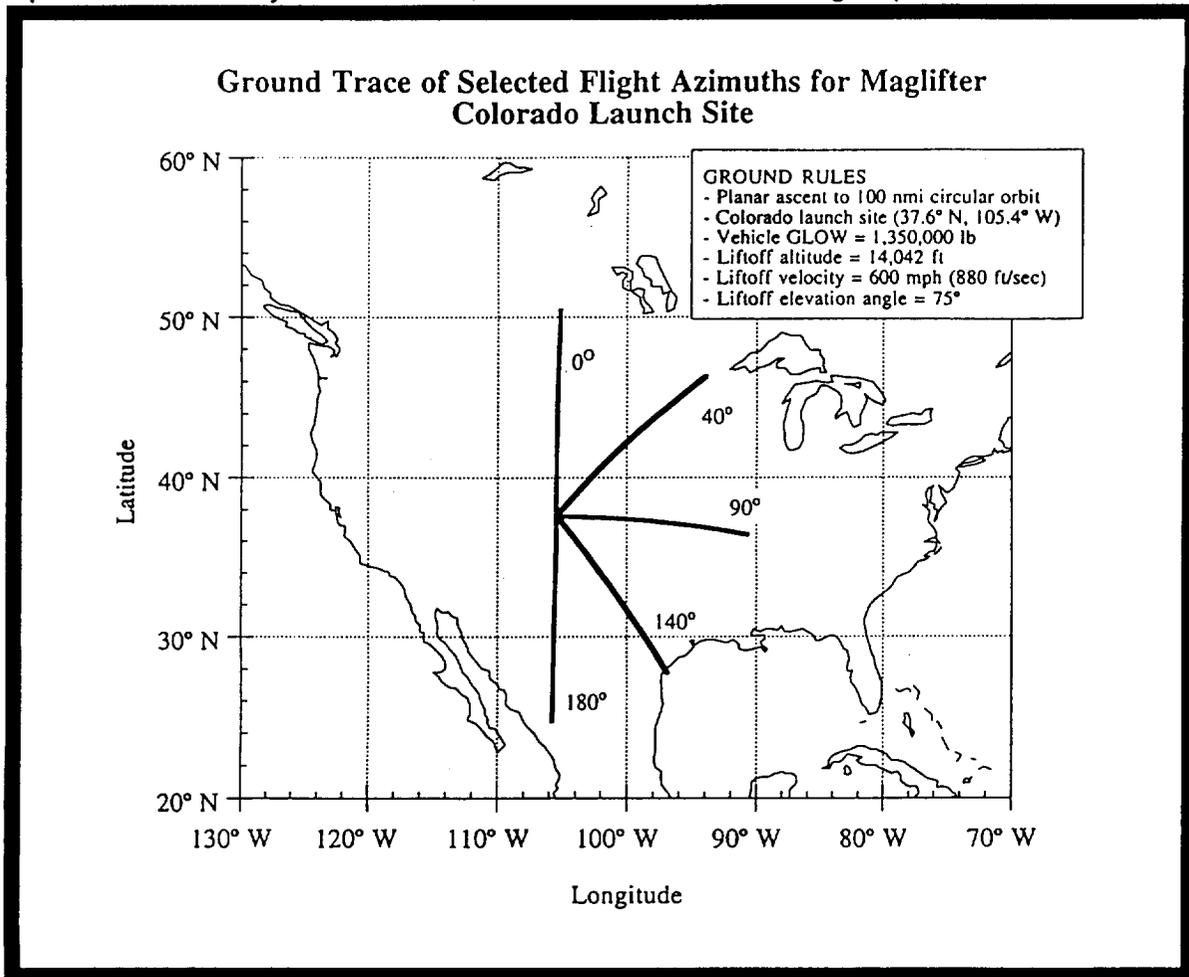
- **DOT:**          $E_c = 1.0 \times 10^{-6}$

What happened was something different. We got to one issue, namely, because it took us over two hours on just that issue, and we had 15 minutes where we kind of put together something at the end of what might be other issues. But the issue we took was the overflight considerations, and that is a potential show-stopper, so what we looked at is launch safety for inland launches, and the bad news about this is it's tough. The good news is, we still have some work-around room. That it's not a show-stopper yet, but we looked at two approaches. One was from the aspect of the range layout. Could we lay out a range in such a way that we could operate safely, and then the second approach was to look at it from the aspect of expected casualty estimates and was there some way we could work with the variables that you arrive at there. What we have as a basis for experience is currently what is used on the existing ranges, like launches out of the Cape, for example, is you need to achieve an expected casualty value of

something on the order of three times ten to the minus fifth, and DOT has a figure tucked away that's ten to the minus sixth.

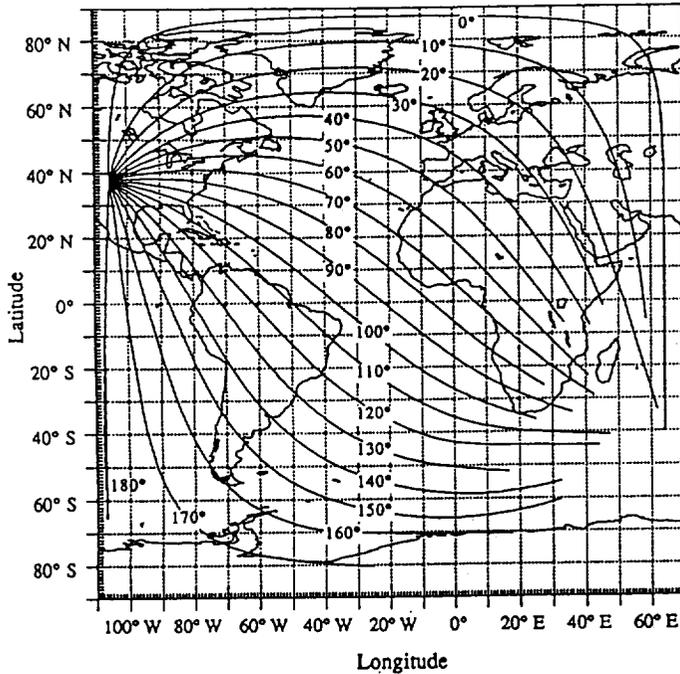
UNIDENTIFIED SPEAKER: Under investigation, I might add.

MR. CHISHOLM: Yes. So let me talk first to our -- look at the range layout problem, and what I'm stealing here are some very good slides that were provided to me by Jeff Samella, who is a member of our group.



What you have here is going from zero to 180 degrees launching out of Colorado. These are impact point traces, and you'll notice that they end out here. Given the launch, that's the point at which if the vehicle achieves orbit, there's no more chance of an impact down here. Now, the catch to it is these impact point traces do not bear a direct relationship to the ground track of the vehicle. Let me show you.

**Vacuum Instantaneous Impact Point (IIP) Traces for Maglifter  
Eastern Launch Azimuths  
Colorado Launch Site**



**GROUND RULES**

- Planar ascent to 100 nmi circular orbit
- Colorado launch site (37.6° N, 105.4° W)
- Vehicle GLOW = 1,350,000 lb
- Liftoff altitude = 14,042 ft
- Liftoff velocity = 600 mph (880 ft/sec)
- Liftoff elevation angle = 75°
- IIP traces as shown end within 1 sec of actual IIP vanish point (2 sec for 170° and 180°)

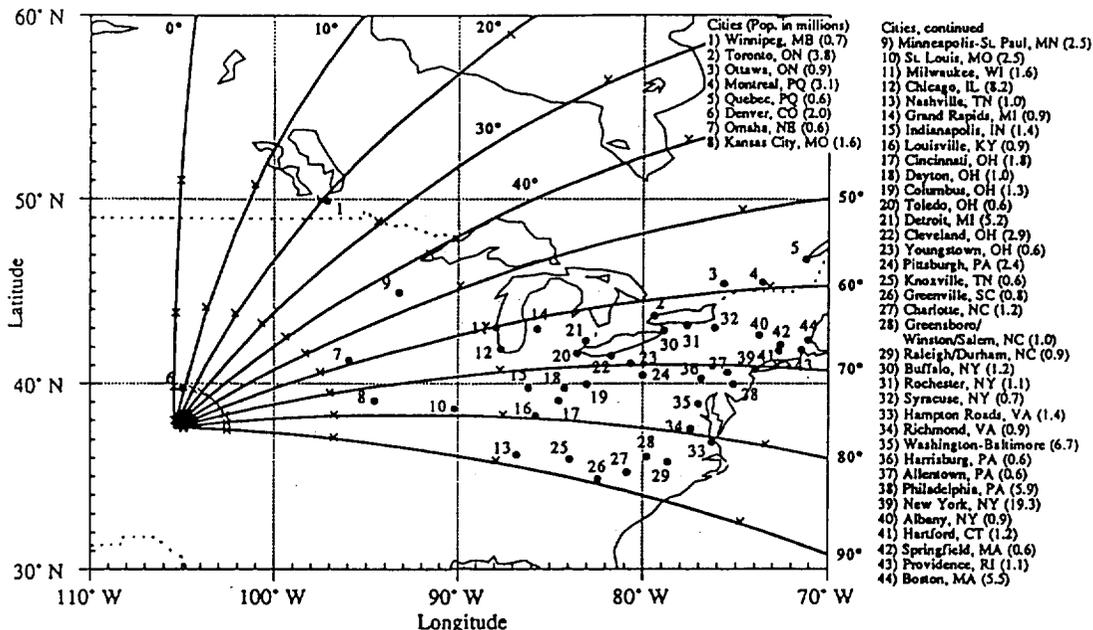
The orbital inclinations corresponding to the launch azimuths shown on the plot are given below:

Launch Azimuth	Inclination
0°	87.5°
10°	79.6°
20°	71.9°
30°	64.5°
40°	57.6°
50°	51.2°
60°	45.6°
70°	41.3°
80°	38.5°
90°	37.6°
100°	38.7°
110°	41.7°
120°	46.3°
130°	51.9°
140°	58.4°
150°	65.4°
160°	72.8°
170°	80.5°
180°	88.4°

See, here, what the impact point traces look like. This is where the vehicles launching out of Colorado would achieve orbit, so you see, they achieve orbit while they're still over CONUS. The problem is, you can get a launch failure, catastrophic launch failure back somewhere on one of these traces back along in this area, but the debris impacts out here, so obviously it's a function of the vector that it's on, and the velocity of that vector.

## Vacuum Instantaneous Impact Point (IIP) Traces for Maglifter Northern Launch Azimuths Colorado Launch Site

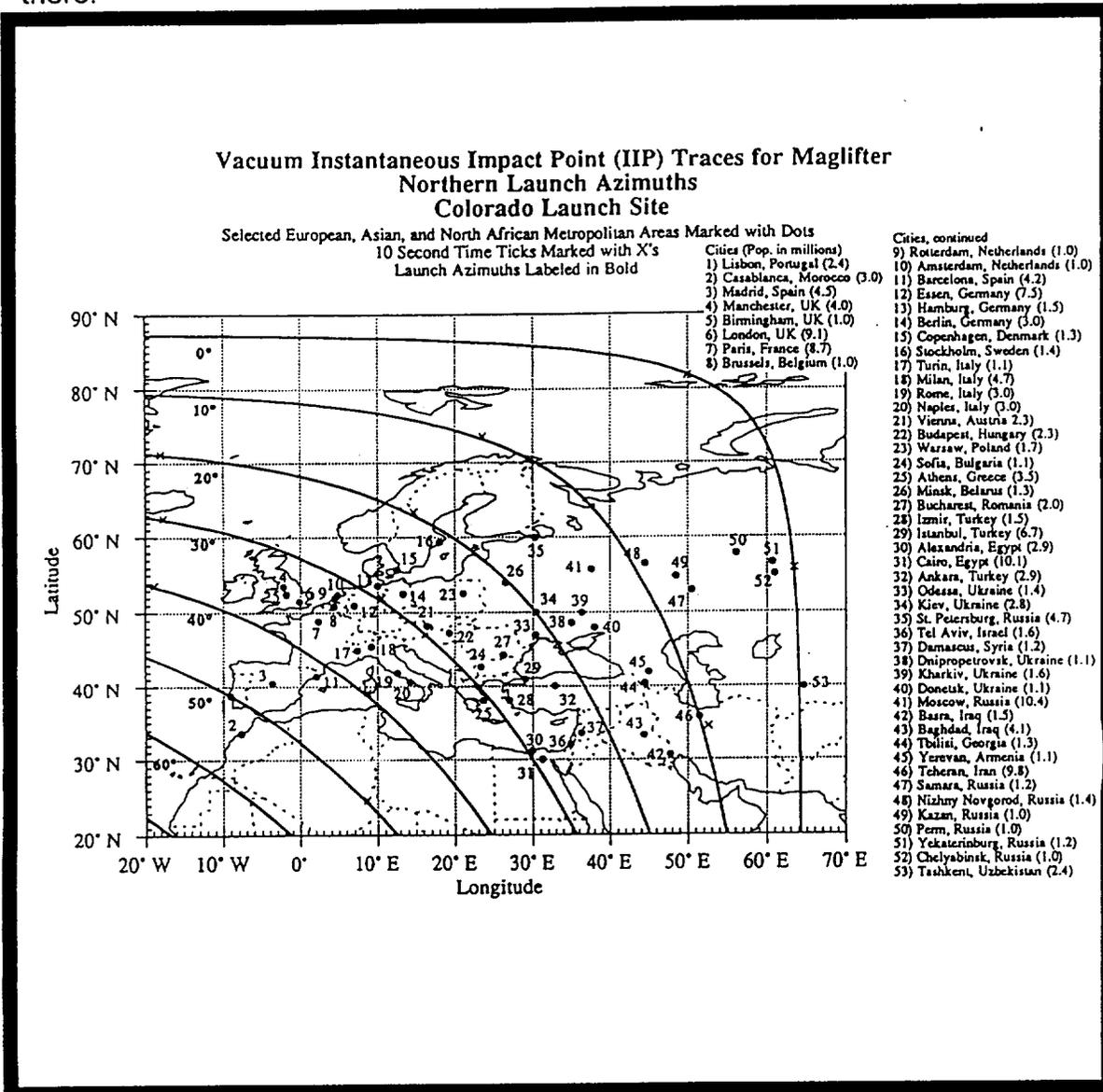
Selected North American Metropolitan Areas (Populations > 500,000) Marked with Dots  
60 Second Time Ticks Marked with X's  
Launch Azimuths Labeled in Bold



Taking a little closer look, these are the launches from zero to 90 degrees. These dots on here represent cities with populations of 500,000 or greater. What you don't get, of course, is the impact of population density, which if you come down the east coast here, this is like a big red wall.

UNIDENTIFIED SPEAKER: Flesh-colored wall.

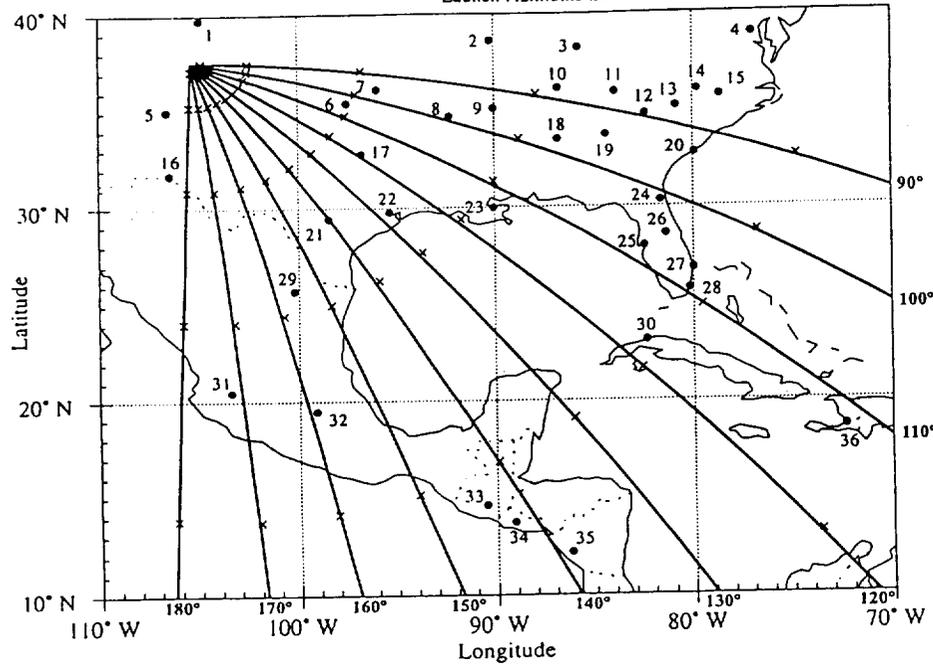
MR. CHISHOLM: Right, flesh-colored wall. At any rate, as you can see, we have a great deal of problem with any launch that's in the easterly direction from there.



The thing, though, that still bears investigation is launches on a northerly azimuth, a la this case, or southerly azimuths. There may be some windows of opportunity in there. Of course, we have to look at those azimuths. For example, on the northerly azimuth, as long as we stay with something around zero degrees, we're out over eastern Russia, that's pretty much okay, but it doesn't take us very long, we start getting down into Europe and another problem area.

## Vacuum Instantaneous Impact Point (IIP) Traces for Magflifter Southern Launch Azimuths Colorado Launch Site

Selected North American Metropolitan Areas (Populations > 500,000) Marked with Dots  
60 Second Time Ticks Marked with X's  
Launch Azimuths Labeled in Bold

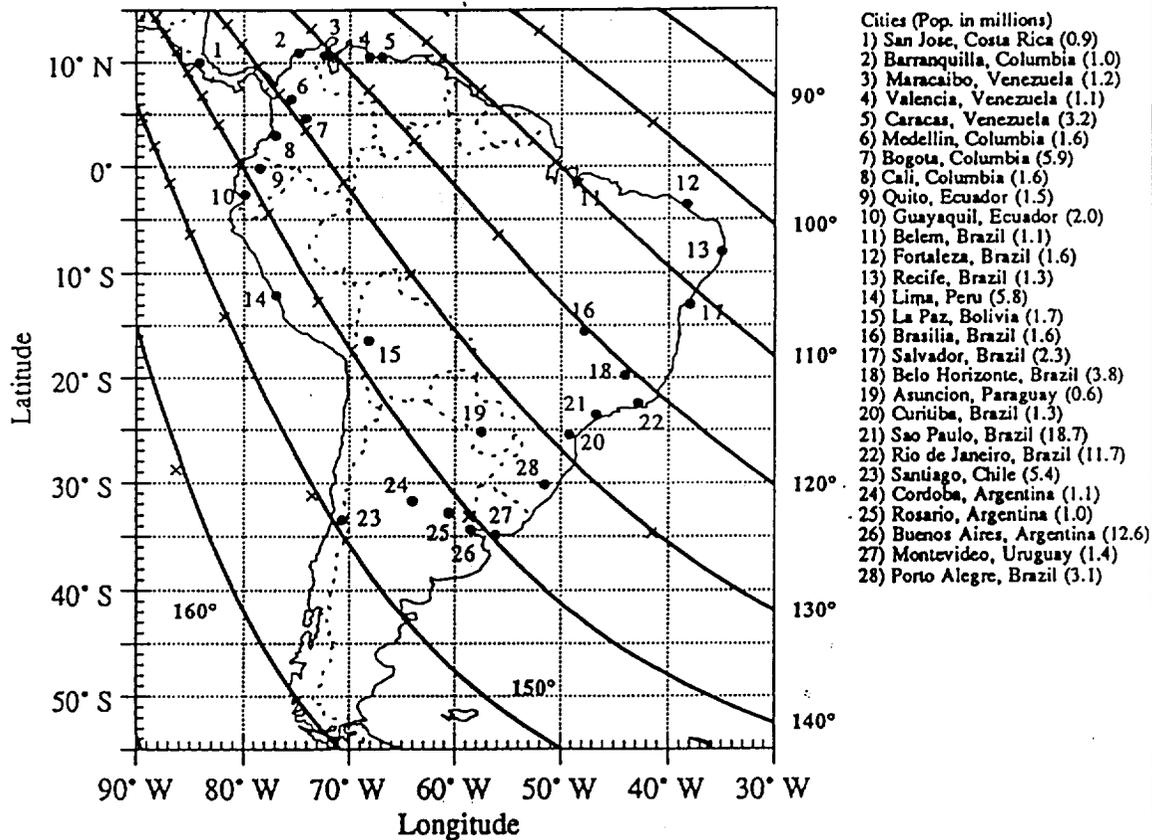


- Cities (Pop. in millions)
- 1) Denver, CO (2.0)
  - 2) St. Louis, MO (2.5)
  - 3) Louisville, KY (0.9)
  - 4) Washington-Baltimore (6.7)
  - 5) Albuquerque, NM (0.6)
  - 6) Oklahoma City, OK (1.0)
  - 7) Tulsa, OK (0.7)
  - 8) Little Rock, AK (0.5)
  - 9) Memphis, TN (1.0)
  - 10) Nashville, TN (1.0)
  - 11) Knoxville, TN (0.6)
  - 12) Greenville, SC (0.8)
  - 13) Charlotte, NC (1.2)
  - 14) Greensboro/  
Winston/Salem, NC (1.0)
  - 15) Raleigh/Durham, NC (0.9)
  - 16) El Paso, TX (0.6)
  - 17) Dallas/Ft. Worth, TX (4.0)
  - 18) Birmingham, AL (0.8)
  - 19) Atlanta, GA (3.0)
  - 20) Charleston, SC (0.5)
  - 21) San Antonio, TX (1.3)
  - 22) Houston, TX (3.7)
  - 23) New Orleans, LA (1.3)
  - 24) Jacksonville, FL (0.9)
  - 25) Tampa, FL (2.1)
  - 26) Orlando, FL (1.2)
  - 27) West Palm Beach, FL (0.9)
  - 28) Miami, FL (3.2)
  - 29) Monterrey, Mex. (2.7)
  - 30) Havana, Cuba (2.1)
  - 31) Guadalajara, Mex. (3.2)
  - 32) Mexico City, Mex. (20.9)
  - 33) Guatemala City, Guat. (1.1)
  - 34) San Salvador, El Salvador (1.3)
  - 35) Managua, Nicaragua (1.0)
  - 36) Port-Au-Prince, Haiti (0.8)

On the southerly azimuths, as we extend those, again, as we start coming up from the 180 degrees, then we start hitting some of the populated areas in South America, but it does look at least on surface analysis, that there may be something we can work, if we study it closer and refine it.

## Vacuum Instantaneous Impact Point (IIP) Traces for Maglifter Southern Launch Azimuths Colorado Launch Site

Selected South American Metropolitan Areas Marked with Dots  
10 Second Time Ticks Marked with X's  
Launch Azimuths Labeled in Bold



In terms of supporting polar launches, which makes Teledesic doable, but for other launches where we've got to go east, that remains a problem. So what we need to look at there is can we do something with the expected casualty figures to achieve the values that we need? And this is just a sample of a range of safety analysis, and can show you some of the variables that go into determining the expected casualty function. What you're looking at mostly is dwell time or duration, that is, it is over a particular point in space, the probabilities that you work out of impact, and this plays with vehicle design. And let's see, okay, we've got dwell time and dwell distance and these work together. Okay, what that leads us to is vehicle design, and attacking the problem treating the expected casualty value.

MR. CASSETTI: Marlowe Cassetti. The range safety implications for countries like Africa and Europe are all based by launches out of the Cape. When you're doing northeast azimuths, you overfly Europe, you overfly Africa, that's independent of most launch locations. The specific problem you have addressing the inland launch is the near end problem really in CONUS that you have. The other ones you can almost say, okay if we're able to wave off those casualty expectations for launches out of the Cape, and I don't think Vandenberg has that problem.

UNIDENTIFIED SPEAKER: They do sometimes by the tip of South America, some of the Atlas launches they did.

MR. CASSETTI: Yes. Still, what I'm saying is, that maybe we really need to look at just the CONUS problem, because that's where the most emotional part of it is going to be.

COL. KIRKPATRICK: Doug Kirkpatrick. The word we had was if we launch three a week, we may increase the probability of conventional damage.

MR. CASSETTI: You're right. I forgot about the higher launch frequency. But in a way, if Teledesic really launches a thousand birds, it's going to have that problem regardless of where it launches. If it's Baikonur or Carou or Cape Kennedy, well, just sort of --

UNIDENTIFIED SPEAKER: Has good insurance.

DR. CARTER: What's the casualty expectancy for line operation?

MR. CHISHOLM: Beg pardon, can you repeat, please?

DR. CARTER: What's the casualty expectation for the average airport?

MR. CHISHOLM: That's one of the questions we need to find out. What, if we pursue the expected casualty value, we came up with a number of points that need to be taken into account and a number of issues that have to be addressed. And one of those is the need to find out what the criteria is that's being used for airports today.

## **OVERFLIGHT POINTS/ISSUES**

- **INCREASING "9s" VERY EXPENSIVE**
- **NEED TO IDENTIFY/UNDERSTAND FAILURE MODES**
- **NEED TO FIND OUT CRITERIA FOR AIRPORTS**
- **PROTOTYPE SITING TO SUPPORT RANGE TESTING**
- **FLIGHT TERMINATION MODES**
- **PUBLIC RELATIONS PROGRAM CRITICAL**

The other thing, you know, is start at the top of the list here. One of the things we look at when we start considering the vehicle, as perhaps the critical variable in achieving the type of safety we want, we start going for nines in reliability. We start driving the cost out of sight. It reaches a point where the curve goes asymptotic and we're up at the peak, so that's going to have to be an issue that has to be addressed. How many nines do we want to go to? We can't say at this point in time, but we need to find out.

MR. HAYNER: You very quickly get to the point where the commercial airline industry can't work.

MR. CHISHOLM: Yes.

MR. HAYNER: We have to get the commercial airline industry mentality. If you keep talking rocket ship mentality and replay the people's hand, you're driven to the boundary and you're out of business.

MR. CHISHOLM: Absolutely.

MR. RODRIGUEZ: If we go to the premise that the reusable vehicle has to be manned, then we might have a problem, but if it be unmanned, why cannot we just torch these like we do with all of the rest of the systems?

MR. CHISHOLM: Actually that makes your problem worse. That's the worst thing you can do is have a destructive flight termination. Because now when we

put vectors cross range, back range, we scatter, and the problem becomes much worse. In fact, that's one of the things that we wanted to look at in terms of flight termination modes is --

UNIDENTIFIED SPEAKER: I suppose a small nuke is out of the question?

MR. CHISHOLM: Right. One of the things that starts driving us into, away from ballistic type vehicles and towards aerodynamic type vehicles where basically when we get to flight termination, we can basically shut the switches off, shut it down, and glide it to an impact zone or a safe area, or maybe, you know, again, once we vent the fuel on board, if we can dump the fuel, we dump a lot of the mass, maybe with at least the small launcher, we may have something that's parachute recoverable a la Apollo, and then that reduces us to only having to worry about the catastrophic failure, i.e., the thing blows up on us, and that's something if we can get it down to that single type of failure mode that we're concerned about, now we can start working to get a lot of the nines for that particular failure.

UNIDENTIFIED SPEAKER: If your vehicle can glide then both of your northern and southern scenarios have a nice large body of water, Hudson Bay to the north and the Gulf of Mexico to the south.

MR. CHISHOLM: Yes.

UNIDENTIFIED SPEAKER: Those are actually a lot closer than they seem.

MR. CHISHOLM: And the other thing, too, that we can look at, if we can maneuver it, maybe we can start playing also with some of the eastern launch scenarios. If we identify and understand fully all of the possible failure modes and what our procedures are for each of those modes, and if we can establish procedures that will get us into basically a safe out. So that's why I had as a second point, whatever vehicle we use, we've got to get in and understand, identify and understand what the failure modes are. We have to spend a lot of time on that. We talked earlier in the group about prototype, and coming back to establishing the overflight safety rules. We felt that the vehicle needs to be involved in prototype testing. Now, whether we do that with the prototype track or we take some other approach to doing prototype testing, it needs to be taken into account, and if we're going to build a prototype track, can we build a vehicle prototype to work with it? I'm not saying that we need to do that. I'm just saying we need to take that into account as a possible consideration of bringing the two programs together early on, and if we do that then that gets into where 'do we do' the prototypes, you know, so where do we site the prototype facility and we would need to take into account the availability of test ranges, White Sands, Edwards, China Lake, take advantage of those, and also, do the prototyping for the vehicle as well as the launcher. And finally, and this has already been

alluded to here, perhaps the biggest thing we need to do is public relations. We need to convince and make people aware that these things are safe, and they're safer than airplanes, and they've got airplanes flying over their head all the time. And that's another thing that tends to drive us towards an aerodynamic vehicle, because people can associate with that easier -- the airplane model -- than they can something that's ballistic, which they tend to associate with rockets, and as everybody has known for 30 some years, American rockets blow up. We'll never get away from that perception, I don't think.

## **OTHER OPERATIONS ISSUES**

### **ENVIRONMENTAL IMPACTS ON OPS**

- **WINDS, ALTITUDE, TEMPERATURE, SNOW, ICE, LIGHTENING**
- **SHOCK WAVE**

### **SINGLE LAUNCHER vs DUAL TUBES/RAILS**

### **MAINTENANCE REQUIREMENTS**

- **SERVICING**
- **REFURBISHMENT**
- **ALIGNMENT**

### **DOT LICENSING/CERTIFICATION**

Now, given that we spent over two hours on that, these are some of the other issues that we came up with that we also feel need to be addressed. We need to take a look, given the fact we're setting this on like a 14,000 foot peak, some of the environmental impacts on operations; namely, you can get to where in Colorado you got the jet stream dipping down, you can get some pretty high winds coming out of there, and that may be a total crosswind, particularly if you've got a northern launch tube. How is that going to impact our operations? We're working at altitude. Do we need people up at the top working at 14,000 feet, oxygen gets a little thin, your ability to work gets a little thin. We're dealing with quite a temperature change from bottom to top. Does that have any impact on our equipment? We've got snow, ice to deal with, and lightning. You need to take all these factors into consideration when we look at our operation. We also

need to look in a related environmental impact at where do we go supersonic? What happens with the shock wave? Is it going to impact things on the ground, and is that going to be a problem for us?

It's already been discussed earlier, the problem of a single launch tube or track equates to a single point of failure, what can we do? Do we need to go above ground and use cheaper construction materials in order to have two tracks to stay in operation, or is there some way that we can tunnel, expand it to get two tracks and whatever. It appears like the cost of tunneling and then doing dual tunnels starts to get prohibitive, so I think we need to look for other alternatives there.

We need to look at what are the maintenance requirements, servicing the system, because we start launching on a frequent basis, and particularly because considering igniting the engines in the tunnel, what kind of impact does that have in terms of servicing and refurbishment? What are our rates? How much time do we have to allot? What about repeated use? Do we have to worry about alignment problems with the track? And we could go on from there.

We need to address the subject of getting, since this is a commercial operation, DOT licensing or certification. What requirements we're going to have to meet to achieve that.

MR. CASSETTI: Again, this vehicle is almost like an airplane. Is there certification and licensing?

MR. CHISHOLM: Yes. Well, I don't know about FAA certification and licensing, that may be a point. One thing we have to do with the FAA is establish restricted air space. And that didn't go on the list, but, yes, we acknowledge that that's going to be a criteria, and always when you start negotiating for restricted air space, it's never easy.

## **MORE ISSUES**

### **PERSONNEL**

- **TRAINING/QUALIFICATION/CERTIFICATION**
- **NUMBERS/TYPES/SELECTION**

### **REENTRY & LANDING SITES**

- **LOCATIONS**
- **INSTRUMENT CONDITIONS?**

Personnel, we need to identify how many people we need, what kinds, how do we select them, what training do we use for them, how do we qualify them or certify them? Those are going to be significant issues for our OPS folks, and finally, we need to look at the issue of reentry and landing sites. We've looked -- mostly we focused on launch, but we need to also start spending some more time on the other half of the operation, which is recovering the vehicle after it has deployed its payload, and that's going to be a cost we're going to have to deal with is having the landing site. Do we use something that's existing and freight it back, like land it at Edwards and then we get it back to Colorado, or do we look to construct a site in Colorado? And if we do, what are the problems of weather? I mean, when it's -- when we've got instrument conditions, basically, the shuttle experiences, you land -- you require VFR weather to land. Can we do instrument landing conditions and if we are going to land instrument conditions, that means we have to have it powered in the final phase of flight in order to be able to execute a go-around, or one person mentioned that there's an approach with GPS differentiation, so we may have accuracy enough to dead stick it in even in the weather.

So these are all things that we covered. We didn't have nearly enough time. All we could do is raise more questions than we went in there with, but we think the number one priority in terms of feasibility study has to be overflight, and we've got to get to that first. And I would submit, too, that perhaps we are the wrong people to be dealing with the cost. I don't know, but everyone I've been meeting in the room, I get this very strong feeling that we're all technically oriented, and I think what we need is to have a meeting where we have some of the folks from the financial sides of our houses in here to help us deal with the cost issues, because otherwise we're getting extreme spread here and rapidly the cost is losing its meaning. That's the OPS panel. Questions?

MR. HAYNER: Mike Hayner from Bechtel. Is the weather a show-stopper?

MR. CHISHOLM: I don't believe the weather can be a show-stopper. It may, you know, there may be launch days we can't launch, but there are also going to be, obviously, a fair number of windows to launch in.

MR. CASSETTI: We've looked a lot at the SSTO, the inland launch situation, and part of it is if you have a trajectory where basically for a vertical takeoff vehicle, you're in a lofted trajectory, you basically get out of FAA air space before you leave the confines of White Sands Missile Range, so in a way, you're in restricted space over the range, if you will. Now, that's not to say you haven't mitigated the instantaneous impact for other parts of CONUS, but at least you can comply if you think of this thing as potentially an airplane, a rocket, something that does fly back, you are dealing with FAA/DOT kinds of considerations. The other thing, too, that's an aspect that may have been overlooked is that when you deal at the Cape or Vandenberg with range safety, you're dealing with the big gorilla on the base.

MR. CHISHOLM: Yes.

MR. CASSETTI: They are king of the heap. I mean, a four star general can't turn them around. You're going to have it different if you're in a state-owned, you know, who's the range safety officer, you know, or who has that authority? It's an interesting situation, but you may be able to fly a heck of a lot more than somebody who's flying out of one of these other ranges. I think Randy Joslin went to Russia and he got some eye-opening experiences on what their range safety is. They don't have destruct systems on their vehicles in Russia, and they claim -- isn't that what they told you? Also very limited.

LT. COL. JOSLIN: We asked the Russians if they had a command destruct system and we were thinking in our American mentality that that meant they put explosives on the vehicle and destroyed them, and the answer kept coming back from the translator, "Oh, yes, we have that system," and then we finally peeled the onion back. What it was is they have a system on many of their vehicles, the vehicle senses that it's departed from its trajectory at which point it sends signals to the engines to shut down, then it's ballistic from that point, that's their self-destruct.

MR. CASSETTI: They also claimed they never killed anybody.

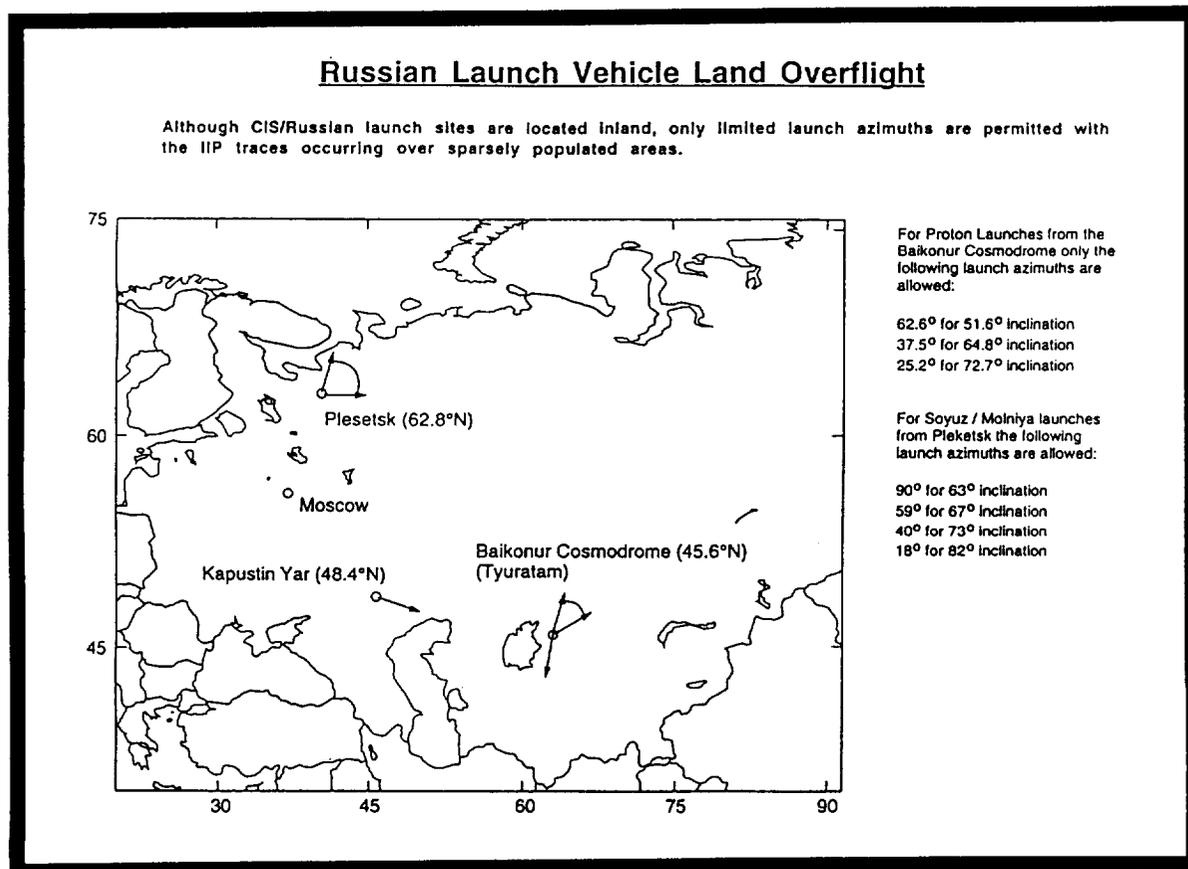
LT. COL. JOSLIN: And they went, "In 35 years," and they went just like that (knock, knock, knock), "we never had a problem."

MR. CHRISTIE: Ralph Christie with Merrick. You started to talk a little bit about the range of vehicles and how it might enforce the impact limit lines. Was there much talk about the Mark I through the Mark IV or whatever --

MR. CHISHOLM: No.

MR. CHRISTIE: -- different vehicle architecture, which ones are more sensitive to this than others?

MR. CHISHOLM: No, we did not get into that. We stayed generally with the lower end, small, medium class, aerodynamic mainly, because as we played with this, as I say, very early on, maybe that's the big thing that we got out of our group is aerodynamic vehicles became very attractive when you start trying to wrestle with this issue. Ballistic becomes a lot tougher.



COL. KIRKPATRICK: Doug Kirkpatrick again. I might add, I was in your group and Jeff just repeated, I'm not sure everybody heard him, but in Russia, because they are used to launching inland, not along the coast, we all think that, gee, they must do it very safe or whatever, but Jeff pointed out to us, it was an eye-opener to me, that Plesetsk has only four azimuths that it can launch imperially and Baikonur has three azimuths that it can launch in, so it is also very range safety oriented and restrictive and very limited in what it can launch, and that drives

them to interesting orbits on some of their satellites that we don't -- we wonder how come you did that, and the reason is, range safety. They don't have a choice.

DR. BLOW: One more question.

MR. CHRISTIE: The question of weather came up. As far as I'm concerned, they have been launching vehicles out of Russia for years in the snow and bad weather and anybody that has been at Poker Flats, it's not grand, it's all suborbital, and ready to go like a commercial launch facility up in Churchill, so I don't see that as an issue. Does someone see that as a show-stopper, the weather? I mean, obviously, the launch rates are much higher.

MR. CASSETTI: We're just saying it has to be built-in.

MR. CHRISTIE: That's what I'm saying, you don't see it as a fatal flaw?

MR. CASSETTI: No.

UNIDENTIFIED SPEAKER: We don't have hurricanes like the Cape does.

MR. CASSETTI: Moving here from the Texas Gulf Stream, they've had higher winds here than they do in the hurricane alley on a regular basis, and they don't call them hurricanes or cyclones, they just say, "100 mile an hour winds. We lost a few roofs and it will be sunny for the rest of the day."



## **SESSION 5: IMPLEMENTATION PLAN**

**Chair: Jim Lowe, Raytheon Engineers and Constructors**

DR. BLOW: Our final session is going to be led by Jim Lowe, Raytheon Engineers. He's going to wrap up all these loose ends and talk about the implementation plan.

MR. LOWE: I'm Jim Lowe from Raytheon. I work out of Albuquerque. That's one of the more pleasant places on the globe. And heading up the implementation plan, the agenda was to talk about the MRC organization, legislation and policy, legal liabilities, private and government financing, dual use of spin-offs, land acquisition and environmental issues. We didn't have any time left over.

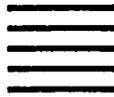
I talked to my boss and told him I was coming to this meeting and he said, "What are you going to do?" He asked, "What's the drill?" I said, "Well, I'm going to be a session chairman and sort of a facilitator," and he said, "Why you particularly?" And I said, "Well, I've been working on the SMES program for seven years, so I worked on MagLev, so these are sort of enabling technologies." He said, "Well, you know, you're a marine engineer, advanced degree, and there are no shipyards left. You have an advanced degree in nuclear engineering and there hasn't been a plant built for 30 years, so you're supposed to be the facilitator?" I said, "Yes. In ten minutes I'm supposed to tell them essentially everything I know as a stalking horse, and then let them ask questions." I asked if he had any suggestions?" He said, "Well, in those ten minutes, I suggest you speak very slowly!"

Fortunately, I had a very able group supporting me. So I'm going to talk about the implementation plan, just give you a few highlights. This is sort of interesting, a viewgraph that I picked up, which I recognize everybody is not going to be able to read this, but this was from a one-time administrator of the Federal Railroad Administration talking about MagLev.

## T R A N S P O R T A T I O N   V I S I O N

The High Speed Rail/Maglev Association was organized in 1983 to promote high-speed ground transportation service in North America as a necessary addition to our transportation system. The Association's sole purpose is to promote the design, construction and use of high-speed ground transportation. ≡ High-speed rail is a generic name for a family of technologies, both steel-wheel and magnetic levitation systems. Without a passenger fatality in more than 30 years of operation in Europe and Japan, high-speed rail is the safest form of travel in the world. ≡ Establishing these systems in North America requires strong collaboration among industry interests. Our membership is among the most diverse of any similar organization. It includes representatives from the: • Financial Community • Engineering and Design Professions • Labor Unions • Construction Industry • Electrical Utilities • Rail Equipment Manufacturers and Material Suppliers • Service Providers • National, State and Local Governments • Universities and Research Facilities • Aerospace Industry. ≡ Membership is open to all who want to become involved in this dynamic and growing industry. We hope you will join us in bringing the benefits of high-speed ground transportation to the public. ○

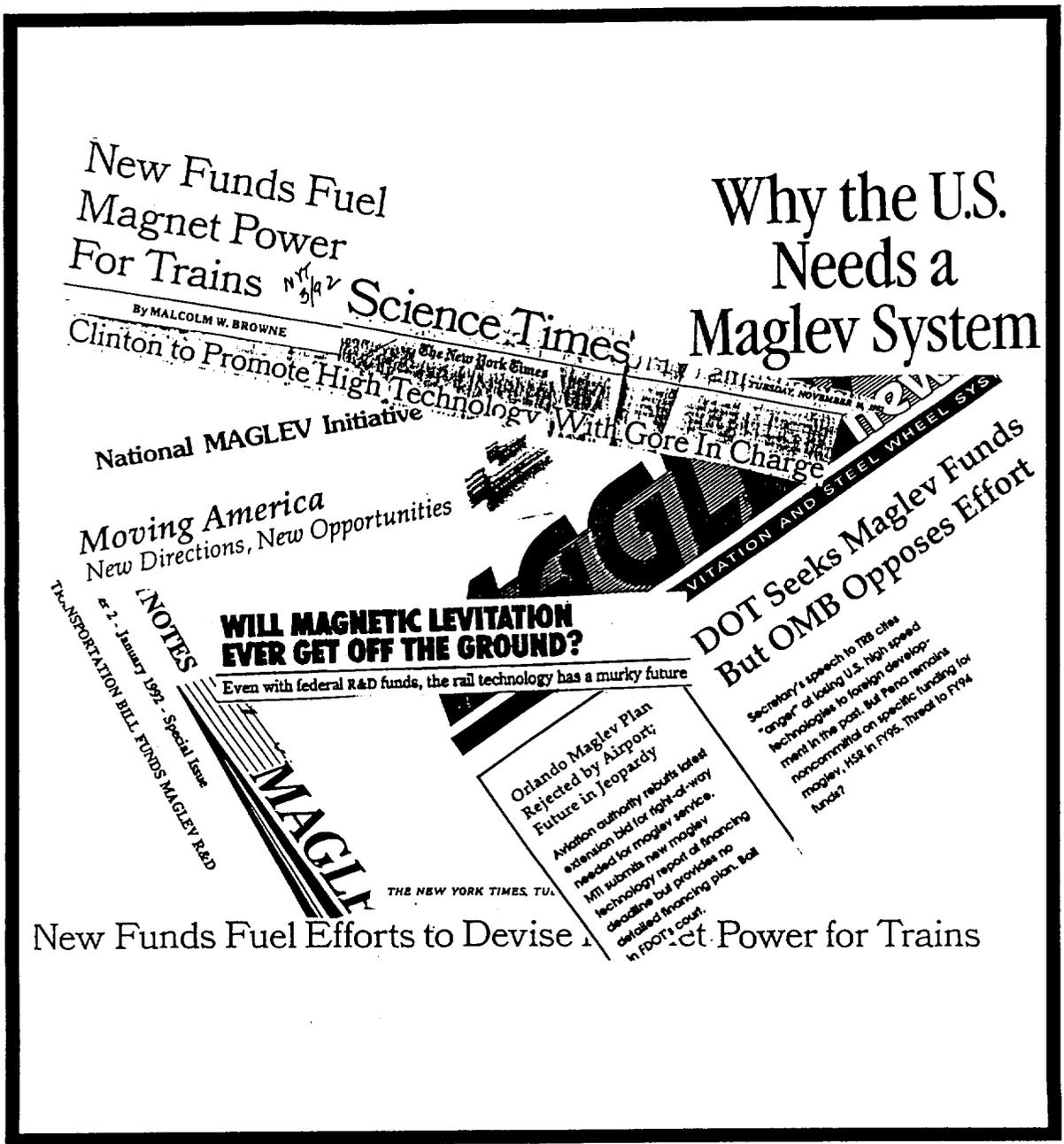
— JOLENE MOLITORIS FEDERAL RAILROAD ADMINISTRATOR



"WHAT A GREAT OPPORTUNITY YOU HAVE PROVIDED. NOT ONLY FOR ME BUT FOR EVERYBODY. YOU HAVE DEVELOPED THE LARGEST COALITION IN THE WORLD TO PROMOTE HIGH-SPEED RAIL . YOU DESERVE ALL THE CREDIT FOR THAT."

And the quotation was, "What a great opportunity you have provided. Not only for me, but for everybody. You have developed the largest coalition in the world to promote high speed rail. You deserve all the credit for that." And that was almost 14 years ago.

A funny thing happened on our way to the forum. If you look at the headlines I mentioned to the group, you could make up a montage which I trimmed out of the papers, and I could have made-up five of these!

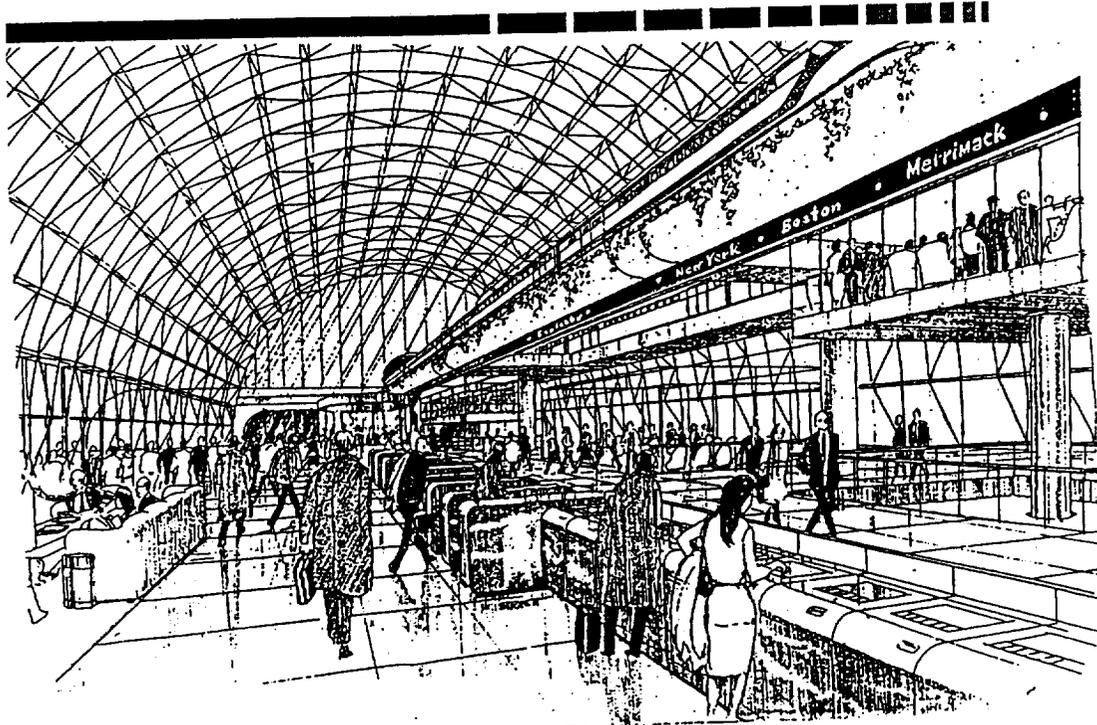


"Clinton to Promote High Technology With Gore in Charge."

"DOT Seeks MagLev Funds But OMB Opposes Effort," et cetera, ad infinitum.

Q: Which Path Should I Take?  
A: It Depends Upon Where You Want to Go!

Lewis Carroll



So one of the real questions I suggested to the group, the issue sort of comes down to this from Lewis Carroll, I quote, Question: "Which path should I take? The answer: "It depends upon where you want to go!" So with that in mind, the question is where do we want to go? We're talking about organizational aspects. This is another very interesting report, which I consider to be completely relevant, and I recognize that that can't probably be read either, but it's out of the General Accounting Office statement back in '93, and it talks about the MagLev and high speed rail, and the relevancy here at least in a couple of sentences is worthwhile recognizing.

## “Private Financial Community Views HSGT As A Risky Investment”

“A general unwillingness to commit private and public financial resources to American HSGT projects is the principal reason why no such projects have progressed beyond the planning stage. On the basis of the projects and analyses that we reviewed and on discussions with members of the financial community who have experience with major infrastructure investment projects, we believe that unless the federal government underwrites a large part of the risk and assumes a larger role in HSGT financing, these projects are unlikely to be built. HSGT development will require a long-term commitment of capital and resources. Because there is little assurance that these systems can earn a positive return on investment capital, they are considered to be very risky investments by private investors.”

Private investors will review HSGT projects to determine if the potential return on investments are commensurate with the level of risk. Equity investors want a correspondingly high rate of return, as high as 30 percent according to some analyst, for investing in a high-risk venture. Providers of debt-capital also want to be certain that the system will generate revenues to pay the interest and repay principal...”

*State of Kenneth M. Mead  
Director, Transportation Issues  
Resources Community & Economic Development Division  
GAOT-RCED-93-23*

“A general unwillingness to commit private and public financial resources to American HSGT projects is the principal reason why no such projects have progressed beyond the planning stage.” Further on down, “Because there is little assurance that these systems can earn a positive return on investment capital, they are considered to be very risky investments by private investors.”

And then in the second paragraph, “Private investors will review projects if the potential return on investments are commensurate with the level of risk.”

## \*GAO Strategic Comments

- "...Unless the federal government assumes a major role... thereby reducing the perceived investment risks, private capital generally will not be available."
- Several Strategies (Suggested by GAO)
  - Financial & Administrative Assistance In Early Stages
  - Loan Guarantees
  - Extend Tax Exempt Status to Debt
  - Revolving Loan Programs
  - "Value-Capture" Strategies

\*GAO/T-RCED-93-23

They went on to comment in a succeeding GAO report before the Congress, that "Unless the federal government assumes a major role, thereby reducing the apparent risk to the investment community, capital generally will not be available," and they suggested various strategies. The problems they defined, and I'm speeding along here, I wanted to make this like you talked about our insurance, where the Prudential Insurance manager stands up and laughed, but out of deference to the General, I couldn't do that.

## **PROBLEMS**

- **PERCEIVED TECHNOLOGY RISKS**
- **POLITICAL RISKS/DELAYS**
- **LACK OF DEFINITIVE REVENUE PROJECTS**
- **EQUITY RETURN**

But the risk that we talked about were these and these are highly relevant to what we're trying to accomplish as an organization to go on. What are the perceived technology risks?

What are the political risks? And how many delays are you going to get out of this program? And if you start looking at the various secretariat levels, every single department of government is involved. Whether you're talking about Department of State, Department of Defense, Department of Energy, Department of Commerce, Interstate Commerce Commission, NASA, FRA, EPA -- complicated problems -- so there's going to be risk and delays unless we recognize them and try to structure and respond to them.

A lack of revenue, and we talked about that. Some of my predecessors here talked very eloquently about defining that, and again, for the investors, is what kind of equity return are you going to achieve? And Col. Joslin talked yesterday, which I thought was very interesting, in defining the number of launches and the perception that, is there a market and can we respond to it on a timely basis?

# U.S. May Let Contractors Run Shuttle

By WARREN E. LEARY

WASHINGTON, May 21 — The National Aeronautics and Space Administration is developing plans to transfer the operation of the nation's orbiting space shuttles to private industry, a prelude to a day envisioned by many experts when commercial operators will own and fly most of the rockets taking payloads into space.

NASA officials said last week that they were planning to consolidate at the Kennedy Space Center in Florida much of the space shuttle work now being done at several space agency centers around the country and to shift responsibility for day-to-day, flight operations from NASA employees to contractors.

In proposals announced on Friday, the NASA Administrator, Daniel S. Goldin, said one way to cut costs could be to restructure the space shuttle program so that a single prime contractor would take over most routine tasks on the ground.

Studies by the agency, private consultants and industry suggest that NASA could reduce its \$3.1 billion annual operating budget for the shuttle fleet by \$1 billion if it let experienced contractors run the system, stopped testing the shuttles' experimental vehicles and more to commercial cargo planes, and reduced the number of Government workers needed to support or audit shuttle operations.

"We want to get NASA out of the business of operating rockets so that it can concentrate its resources on cutting-edge research and development," Mr. Goldin said in an interview.

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Mr. Goldin said last March that he favored turning present and future launching business over to industry. He endorsed a new NASA program to finance research on a new generation of rockets to replace the shuttle. The new rockets would be financed, built, owned and operated by private companies.

Under this \$850 million program, known as X-33, three groups of companies will design rockets, and it is hoped that experimental versions of one or two of the contenders will be flown by the end of the decade. The goal is for industry to develop the winning entry into a commercial vehicle that the Government and other customers will rent for missions.

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Christopher Kraft, a former director of the Johnson Space Center, concluded that consolidating operations under a single contractor was the best way to increase efficiency and reduce costs.

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## G.O.P. BUDGET CUTS WOULD FALL HARD ON CIVILIAN SCIENCE

### BASIC RESEARCH AT RISK

Experts Foresee a Crippling Science Establishment and Layoffs at Universities

By WILLIAM J. BROAD

The glory days of the Federal science establishment may be over, science leaders fear, as cuts proposed by Republicans to wipe out the budget deficit fall hard on civilian research.

Under the cuts, annual appropriations for nonmilitary research might drop to about \$25 billion by 2000 from the current level of \$32 billion, if total reductions of \$24 billion come over the period.

At risk is the type of Government financed basic science that has paved the way for modern life: men on the moon, explored the deep sea, unlocked the atom, cured cancer, found the remains of lost civilizations, tracked earthquake faults and discovered the chemistry of life among other feats.

Specific casualties of the cut might include atom smashers, new weather satellites, space probes and dozens of large Federal laboratories that study everything from solar power to violent storms.

Republicans say their goal is to trim fat and corporate welfare rather than cripple basic science, which economists agree is a powerful engine for promoting economic growth and high standards of living.

Representative Robert S. Walker, a Republican of Pennsylvania who is chairman of the House Science Committee, said this month that the proposed budget would keep "a robust science policy while providing for the fundamental science base we need to move forward."

But Democrats and private experts say the cuts would undo the Federal science establishment, crippling parts of it beyond repair.

To be sure, science leaders in past budget battles, clearly working in their own self-interest, have been known to exaggerate how painful reductions might be. And some pain might be averted as Democrats and Federal agencies fight the cuts, or if President Clinton successfully vetoes spending bills.

**The space agency wants to quit day-to-day operations and focus on research.**

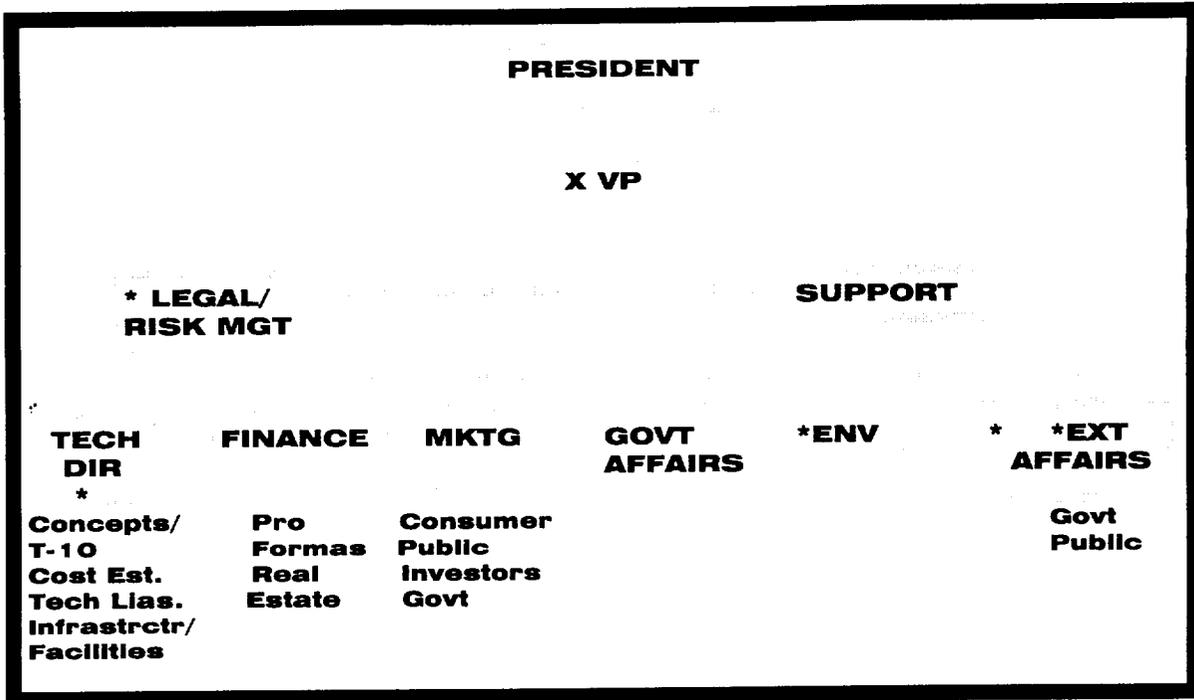
**The space agency wants to quit day-to-day operations and focus on research.**

More national news appears on pages C10-11.

NYTIMES 5/22

This was out of the New York Times on Monday of this week, and had to do with NASA and the space program, quoting the chairman of the committee, "Mr. Gingrich said last March that he favored turning present and future launching business over to industry. He endorsed a new NASA program to finance research, a new generation of rockets to replace the shuttle. The new rocket would be financed, built, owned and operated by private companies." And further quoting, "The space agency wants to quit day-to-day operations and focus purely on research." Obviously, the media does not make policy, but the New York Times does pretty well sometimes in, at least, stating the facts and anticipating them. So maybe all is not lost and maybe what we're talking about here is certainly a very significant meeting in trying to focus our efforts and go on.

And I must admit, consistent with some of the technical comments that have been made and you will see this I think in their presentation, that when I start looking at perceived risk to the investors and the community and the schedule, we are operating on a pretty steep mountain and a very slippery slope. And whether that schedule can be accomplished within the time frame -- I'm going to leave to some of the people before me who have assessed the information, and have the technical objectives in hand. I think they have expressed appropriate concerns.



But going on very quickly, let's talk about the organization. The bylaws, and when I came to this meeting, I had not received in advance either the bylaws or the business plan, and I sat up and read them in some depth and detail last night and I certainly want to congratulate Neil on what has been accomplished. I was pretty impressed when I got through. I went away with maybe a feeling of cynicism to looking at all the perceived problems to the fact that this can be achieved. My only question now is maybe not *if* it can be achieved, but *when* it can be achieved. So that is the key point, I think.

This organization in the bylaws by the way, is defined as an organization in some respects of the people that are going to be involved. It requires a president, an executive vice-president, a financial director, a marketing director, government affairs. Government affairs, we added to that organization. And we feel that in recognizing all the problems, that the organization should be centered around the fact that we need a technical director, which has to certainly evaluate and come down to a standard definition of the standard that we're trying to achieve. The concepts and tradeoffs have to be achieved in a relatively short time. We have

to have some valid cost estimates that are going to support the investor community. There has to be a technical liaison with both Department of Defense and the commercial launch proponents as to how this sled can match with those vehicles. And obviously, it's a problem that I think a lot of people have to look at and respond to.

I think my colleague from Sandia made the comment about this being a difficult problem. And Gary commented on the fact that going from 300 miles an hour to 600 miles an hour is not simply a 2X linear extrapolation of the problems inherent in achieving that solution.

Finally, where I have asterisks, we put in a legal and risk management group, and I think that group has to be an inherent part of the organization.

We have an environmental, which we felt should stand alone as a check and balance. You don't want to subordinate it too far down the organization, and that guy has to be able to go to the organization and report what he senses is happening in the outside community.

And then we have an external affairs, which is both government and public relations.

Marketing has to lean towards the customer, the public, the investor community and relationships with government both at the federal and state level.

Now, I point out that the executive vice-president level I think should be probably co-billeted with one of the other management fellows in the interest of economy in the early stages of the organization.

What do we consider to be some of the critical issues facing the organization?

## **CRITICAL ISSUES**

- **GOVERNMENT ASSISTANCE**
  - **ASSETS TRANSFER**
    - **LAND**
    - **GEOSYNCHRONOUS ORBITS**
    - **TAX EXEMPTIONS**
    - **FCC CHANNEL ALLOCATION**
- **TECHNICAL RISK REDUCTION**
  - **PROTOTYPE DEFINITION/SIZING**
  - **LOW COST DEMO**
    - **SCALABILITY?**
    - **COST?**
    - **SCHEDULE?**
  - **RISK ASSESSMENT**

Along with the tasks laid on us, some of these have already been addressed, and in that organization we felt very strongly that we had to look at government assistance.

What assets literally can be transferable? Land. There is an analog for this, a lot of the land was cosigned over for development of railroads in this country in the last preceding century. Nothing should probably preclude the government from making an assignment of land to us.

Again, the possibility of assigning and giving and granting geosynchronous orbits is a freebie to this organization in being able to go out and market the products.

Tax exempt considerations and Federal Communication Commission frequency channel allocation, includes having to bid on it, that this is going to be a nonprofit group in its infancy. You're going to develop, every element of what we can get out of the federal government ought to be exploited and attempted.

Technical risk reduction, and this sort of begs the question that Mr. Chisholm and some of the other people have addressed and along with the question of Lewis Carroll, where do we want to go? What is a prototype concept definition? What's the standard? What's the sizing of it going to be?

And more importantly, if we are going to have a low cost demo, what are the scalability issues? What is the cost of it? What is the schedule feasibility? I don't think this has really been addressed and some of my predecessors here sort of said the same thing, that there is much concern about this. It is not a 2X linear extrapolation from a 300 to a 600, and scalability is a big problem. Everything I've addressed mostly in my life I've been bedeviled by scalability issues with the exception of the SMES program, which turns out to be 100 percent scalable plus support.

Cost factors. My friend here, Ralph, from Merrick has identified that costs are a humongous problem and a lot of areas remain to be identified, including the power requirements. Chuck had spoke to the fact that -- Chuck Oberly, that there are other ways of achieving power besides SMES. I would agree in the first prototype, SMES certainly is going to be a very expensive item if it's going to be used as a power source for this program. On the other hand, if you went back to the ground base free electron laser program, the original concept there was that utilities would use any SMES system as an asset in their systems with the availability of peaking power being made available to the government for their precise requirements and applications, so there might be a system that can be co-shared with the local utility grid and they would be willing to take advantage of that capability in some of the off-usage periods of time.

## **ENVIRONMENTAL**

- **OVERFLIGHT/FLIGHT TRAJECTORY**
- **LAUNCH GO/NO-GO**
- **AERODYNAMICALLY FLIGHT CAPABLE**

Risk assessment, it's both a legal problem and a technical problem, and the launch orbit overflight considerations are a significant part of that. You're going to a direct, essentially, ballistic launch. You're over, say, White Sands for a very temporary period of time. If you go to an aerodynamically flight capable system with a lower trajectory, then you've got to look at the launch go, no-go criteria. What are the orbits? How do you control it? And Mr. Chisholm addressed some of those, and I thought he did it well.

We recommend that this, from our group, and while we were not the engineers and the technical group assessing this, is we ought to look very much at the aerodynamically or the Case II aerodynamically capable flight vehicle.

## **LEGISLATION/POLICY**

- **ENABLING LEGISLATION**
  - **STATE**
  - **FEDERAL**
- **REGULATORY AGENCY**
- **LIABILITY LIMITATIONS**
  - **PUBLIC**
  - **CUSTOMER**
- **SAFETY**

Legislative policy. Has all of the enabling legislation been put in place? And I think Neil talked very openly about the fact that we're talking about New Mexico, Colorado, Utah, Texas, Oklahoma, potentially California. You start looking at all the enabling legislation that is required, and conceivably some of it by the Congress, if we're going to receive government assets and transfer for some pretty sticky wickets that we have to go through.

What is going to be the key regulatory agency? No matter what we do, it is our opinion that we're going to be faced with the safety issues, that you're going to have government, be it the FAA, NASA, or somebody looking over our shoulder to assure that practical and proper safety practices are being adhered to throughout.

Liability limitations. The first opinion being issued in our group was that, gee, the customer is going to take care of the liability issues for his own vehicle, and we see that continuing. The public liability issue was discounted, but the fact is we have a CONUS, central CONUS launch as opposed to a Canaveral or other areas, and we're faced with the problem it is going to be viewed entirely different. The orbit, the potential impact areas, the liability considerations, the question is,

should there be a liability limitation enacted by the Congress or guarantees consistent with some of the ones that were enacted under atomic energy and nuclear power plants, where there were a number of limits and the provision for liability damage beyond that was being pursued and supported by the government, so a big concern. We feel this is an area that has to be addressed by the organization that we specified.

### **POLICY ISSUES (MARKETING)**

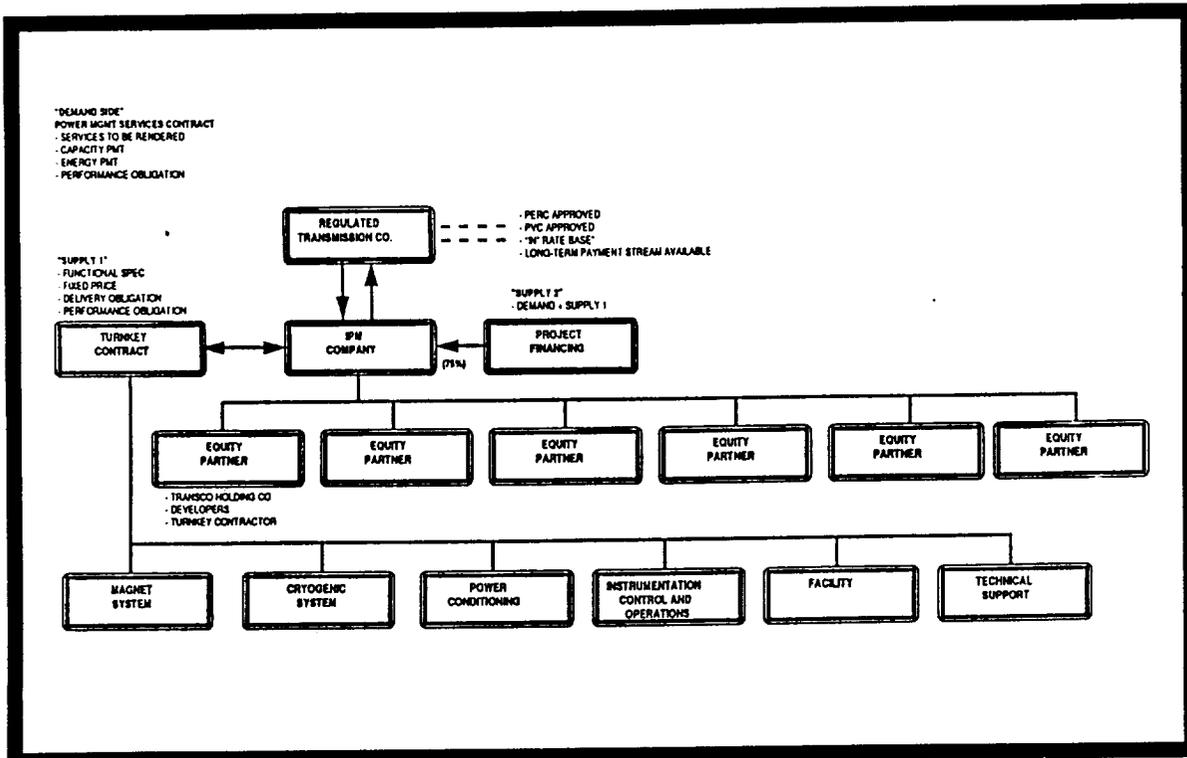
- **ANCHOR TENANTS**
  - **GOVERNMENT (NASA/DOD)**
  - **COMMERCIAL (INCENTIVE PROGRAMS)**
    - **USER FRIENDLY**
    - **COST INCENTIVES (LONG TERM)**
- **NOT INNOVATIVE (MATURE TECHNOLOGY)**

Policy issues for marketing, and a lot of concern about this. If you're going to get the investment community there, we've got to be able to address the possibility of getting anchor tenants, either the government or NASA or DOT, and Col. Joslin indicated the probability of that, which I think is probably true.

Commercial, it has to, and we're talking about the possibility that it has to be user friendly, has to have cost incentives, and it can't be missiled. It has to be as many people discussed before me, old hat, you know, like flying an airplane, and people have got to have that kind of confidence and it has to be addressed.

One of the things that I suggested to Neil is something that I came back with from a meeting in the Department of Energy last December on SMES, and I talked to Dr. Ioddy, who is a USA manager for years, involving the topic of how the meeting goes. "The best meeting I ever had with the Department of Energy," and he said, "Well, how so?" I says, "For the first time somebody in the Department of Energy said they weren't going to do a damn thing for us," and SMES was, as far as they were concerned, a dead program. There's not going to be any money. He said, "Why is that good news?" I said, "I don't have to waste any more time with the Department of Energy."

What we have done since then and some of my Bechtel colleagues are doing the same thing, we're looking at the possibility of joint venture structure and financing where we would form an independent power management company, equity partners would be a turn-key contract, and we would sell on a pay basis the benefits of this system to various utilities.



Without identifying who they are, we are now talking to three different utilities that have expressed keen interest and they would do this on a 15-year basis. I think that, I suggested to Neil, that, hey, \$500 a pound is a goal, and that's very ambitious, \$2,000 a pound is less ambitious, but \$2,000 a pound is a hell of a lot better than anybody else is able to get payload into space, and maybe we have to take in order to flush out the market. Col. Joslin I believe indicated that in going around and talking to the commercial community, there is a reluctance to, you know, say, "Hey, I've got an elephant in here," and say, "Let me see it." "No, I can't tell you what it is. I can't show you this elephant." The fact is that there may be people concealing their long-term strategic objectives in that community, and if you go out and offer them an incentive where you say, "Hey, if we have the system on line, you make no capital expenditures and we will launch for you at \$2,000 a pound or \$2,500 a pound take or pay for all your payloads on a given day, will you commit?" I suspect, since they have no capital investments, nothing at risk, they may very well opt for that as an opportunity having other acquisitions independent of that, which they will still be able to exercise. But at least you can start directing that market. So I suggest this as a possibility of making the program go.

Another thing, I guess we talked about and there was quite a bit of discussion about this, is public relations in this program. Gaining customer credibility, having demos that meet the investor community expectation, and as Sandia indicated, it has to be earning on a measured basis. It shouldn't be so ambitious that we can't take and have a measured set of objectives in achieving that.

## **PUBLIC RELATIONS**

### **PARAMOUNT ISSUE**

- **SELLING TO THE PUBLIC**
- **SAFETY**
- **CONSISTENCY**
- **JOBS**
- **MEETING FOREIGN COMPETITION**

Public relations is fundamental to this program ultimately. As with real estate, location, location, location. If we don't have decent public relations on this program bringing it along, it's a paramount issue, and we're not going to cut the mustard. We've got to sell to the public. It's got to be safety. The program standard has to be identified fairly early on, and as to what we're trying to achieve, it has to be consistent. We can't go out and reverse course every three months. We have got to be able to talk jobs. We have got to be able to talk about a national goal, you know, in our culture here. We're certainly in a country -- I talked to Neville and other people, Chuck Oberly -- we're blessed with a culture right now that has no national goal. We've lost it. Somehow or other the message has to be so important that we start establishing this program in national ascendancy, technology ascendancy, it may be a national goal that we want to achieve.

Certainly we're being threatened by the Japanese every day and this might be an opportunity to save this program for our future. If you listen to the Newt Gingrich third wave, his endorsement of that information technology is essential to our productive future. It's essential to high technology. It's essential to jobs.

So public relations and their part in that organization, our group felt, was very, very important.

### **SPIN-OFFS**

- **TECHNOLOGY CAPABILITIES FOR NATION**
- **MAGLEV GROUND TRANSPORTATION**
- **EMPLOYMENT/HIGH TECHNOLOGY**

And spin-offs, which is the concluding viewgraph, in general, the program has to stand alone. If you're going to get investor money into this, they have to measure this program on what they see as a potential return on their investment in this program. And there are potential spin-offs in other areas, which are technology capabilities that possibly can be transferred into other areas. MagLev ground transportation, other employment, high technology opportunities which might be transferable.

It was generally felt that if we talk about MagLev that may be a downer rather than an upper, because the program has gone through some very disappointing economic analyses that say, "Hey, there's no return on it," and we're not going to get there saying, "Hey, the big spin-off of this is going to be high speed MagLev transportation from Boston to Washington D.C. at 300 miles an hour." We all know that's not going to happen, at least in my lifetime, and it would be a long time away. So the program has to stand on its own. Technology capabilities for the nation and how we sell it in that respect we all felt was very important, and obviously, I've touched on many of the same areas that my predecessors have touched on, in the technologies areas, so I was supposed to start at 3:45. It's taken me two minutes to give you all that information. All right. Thank you.

DR. BLOW: Questions?

MR. CHRISTIE: I have a couple. Ralph Christie of Merrick. You looked at the MRC organization, you said you reviewed the document last night. Do you have any feelings on whether that is the proper organization or best way to proceed in driving this program? Are there other options or other organizations, pipes that fit as well?

MR. LOWE: Well, let me throw that back up as a discussion point here. Yes, we changed it, and the bylaws have spelled out an organization which is generally consistent with how you would address a lot of these programs, but again, the

asterisks I pointed out on here are the technical director, the environmental, which I think has -- we all felt -- when I say I, I speak for the group, so I do not mean this to be egotistical. I had a very good group of people in there. External affairs, public relations have to be outside. The other ones, finance, marketing, government affairs, executive vice-president and president were all in the bylaws. I frankly feel that the executive vice-president at this point is inappropriate, that maybe one of these other jobs can co-share that job, wear a double hat in the interest of economy and bringing the program along. One thing I forgot to mention in external affairs, once you have a conceptual definition and a tradeoff, I think you've got to go big time and very forward, very aggressively in the Denver newspapers, in the *Albuquerque Journal* and elsewhere, do this, if possible, with a first class presentation which the material was already there in most cases, talk about capabilities, jobs, employment, or maintaining a technological lead.

Then following that, the general feeling was that one of the things that should be done very early is have a market survey or a public survey on some sort of a nonidentifiable basis to find out what the public reaction is going to be. How many environmentalists? How many 'not in my back yard' types are going to stand up and scream, and what is the sense of the public reaction to that going to be? And without that and without selling it -- you've got to sell. This is a program that has to be sold. Without that, all the technology on God's green earth is not going to make this program happen.

COL. KIRKPATRICK: Doug Kirkpatrick again. One of the things in Operations we thought because of PR and we thought about PR quite a bit, was a lot of the people would say, "You're not going to scar my nice-looking mountain, are you?" And unless we own the mountain, maybe the company owned the mountain, still will get a lot of environmentalists riled up, "You're not going to put a rail up my mountain, or in this beautiful mountain and destroy the natural beauty."

MR. LOWE: Well, let me make a point maybe which correlates back to my activities in superconductive magnetic energy storage. There were five sites in the United States; Monahan, Texas; White Sands; Hanford, just north of Madison, Wisconsin, and where was the other one? The interesting thing, and you've got to live in Wisconsin to appreciate this. No matter whether you're talking to the Alcoholics Anonymous or the gay community or whatnot, there are 15 different shadings of political opinion in every one of those groups. When you went elsewhere, whether you're talking Monahan, White Sands, Hanford, people thought jobs -- boy, when you talked about employment, when you talked about technology, what this meant to the program and to the area, big support. Tough problem in Wisconsin. I don't think we could have ever gotten the program endorsed or built in Wisconsin despite the fact that its a public utility. So again, public relations, you know, who owns the mountain, and who that mountain is

going to impact and whose back pocket and whose wallet is affected, I think makes a big difference, and where it's built and how it's sold is critical.

By the way, Ralph Christie, I think, brought up something that should not be overlooked. The environmental impact statements have to be filed on this, and you've got like a six months filing period and after it's filed, there has to be a public hearing, preliminary and then there has to be final, and, boy, even if you're a wizard, that's a one-year process, and the environmental impact statements on the areas, and you start looking at this program to be brought along by the technical group fairly early on to start developing and working with the Army Corps of Engineers who are likely, no doubt will be the ones that will assess the environmental impact statement.

MR. TORGERSON: A key part to that is, we talked about in our group, is that the description of proposed action alternatives would have to come out of that technical group, you know, and back it up two and a half years and that really forces some early decisions on what the system is going to look like, what the facilities are going to look like. You really can't commit resources without filing a decision, so a lot of decisions have really moved up the pike just because of the environmental impact statements.

MR. LOWE: Absolutely. Whether you're going to be able to maintain the investment, community interest during that period of time while you're still hanging on the environmental limb, which God knows there's a lot of people willing to saw it off, is going to be a tough question, kiddo.

MR. CASSETTI: It's my own personal belief that large government investments have to go into this, because of the fact that it's major research, development, technology, and only the federal government can afford it. Did you guys touch on how you sell this to the government to convince them, since these are the same kind of issues you looked at in other Mag rail systems and other energy programs, et cetera, did you touch on that at all in your sessions?

MR. LOWE: We only had two and a half hours. No, I think the answer is, yes, we briefly touched on it, and one of the thoughts that got generated is, you've got to talk to people like Gingrich early-on through people like Domenici and your senators here in the state, and excite his attention.

Gingrich, and I was privileged to go to the War College and have dinner two evenings in a row with Newt Gingrich, and he's a remarkable, I think, almost brilliant individual, and whether that's going to be adulterated by ambition here is a good question. He's very consistent. He's got a long memory and he's very much endorsing this sort of thing in other public statements, which I can probably cite and invite to the General's attention, and I guess I think if you start getting

endorsements at that level of the Congress, along with people like Pete Domenici, the program can be sold and you can get support.

A lot of it, along with one of the things we suggested, I think, has to come in is asset transferal and how you achieve that and get grants and tax freebies is a tough road as well, because one of the things, by the way, and I mentioned that the society, the National French Railroad Association or whatever it is in their terms, formed a similar organization that is being proposed here by the MagLifter group, nonprofit, and they kept all hardware manufacturers and suppliers out of direct control. And as a hardware manufacturer, you know, in Raytheon, I am sympathetic to that, because, you know, there are other people that feel, "Hey, I'm getting in here early in the trenches, I'm going to get some of the hardware that the program develops." Yet there is still the residual effect that when you start going public, people say, "Well, who's participating in this program?" "Well, Raytheon is participating, and XYZ Manufacturing Corporation." Those people are running a scam and they're just trying to get business for themselves. The organization has to be set up with some degree of cleanness, so the governing body at MRC and even the succeeding organization if you go to Phase III, has to be impervious to scam accusations, that people are cutting up the pie internally for themselves.

MR. RODRIGUEZ: Just one observation in reply to Marlowe, and that is, when they put this railroad to span the continent here, I'll bet you that railroad didn't take a nickel of government money to do that. I'll bet you the percentage of gross domestic product, that this project was a fraction of what that railroad cost, and yet they did it all with private capital.

MR. CASSETTI: Well, the only thing I can think of is about a year or so ago, I was at a conference where somebody from the government was expounding about how the next generation launch system was going to be funded entirely by private capital. And so the question was asked from the audience. "Would everybody in the audience who thinks private capital is going to fund this, raise their hand," and there were quite a few hands raised. And then the guy who asked the question said, "Now, put your hand down if you're with the U.S. government," and every single hand went down. There wasn't one person from private industry that said, "Yes, we are going to fund this."

DR. BEER: We need to interrupt just a second. Also in what you read in the bylaws, there is a science advisory group, and there's a management advisory group. What is missing is the strategic planning group -- the effort to devise what the plan will be for public acceptance, government acceptance, and the plan we would brief to CEOs. Neville Marzwell is going to speak to this, but first, can we give John Mankins, who has got to get all the way to DIA, and so is going to have to depart before we finish, a couple of minutes?

MR. MANKINS: Now, my presentation. I just wanted to say, the cookies have been great. I've enjoyed very much the last day and a half of discussions in this working meeting. I think that it is a huge triumph to end up with a group of individuals from so many different organizations, and for everybody that's here, a common thread, that the notion of electromagnetic launch assist is *not* undoable.

There are a lot of issues. There are questions of development pace and the question of technical uncertainty, a lot of issues that have been raised in the discussions, but believe me, when I started talking about this a couple of years ago, it was not only unthinkable -- it was not only unproven, it was unthinkable. So this represents to me, this meeting and the discussions, terrific progress, and I look forward to the proceedings from the meeting and the contribution that they're going to make from the standpoint of making electromagnetic launch assist and related concepts a part of NASA's thinking.

I know there are a lot of other activities ongoing in the Air Force. I just walked out with Capt. Clapp from Phillips Lab who's on Colonel Sponable's staff, and he has a variety of additional ideas, but I think that this area of investigation is one that has enormous promise.

And I wanted to offer -- I know this is Gen. Beer's meeting, but I wanted to offer my own thanks to you for your participation and involvement. Thank you very much.



**MAGLIFTER PANEL DISCUSSION  
MAY 24, 1995**

**COLORADO SPRINGS, CO**

Panel: Bob Turman, Sandia National Laboratories  
Joe Haney, Rockwell International  
Ralph Christie, Jr., Merrick & Company  
Chris Chisholm, ANSER Corporation  
Jim Lowe, Raytheon Engineers & Constructors

Moderator: Dr. Larry Blow

DR. BLOW: As our last segment, could we have all the session chairmen please arrive here at the front table, and take any remaining questions that we might have from the group. I think it's been a very compelling session. The issues have been hard. The people have been smart and there's still a lot more to do. I think this is going to be a really excellent project. Are there any questions to start out with?

COL. KIRKPATRICK: Yes, sir. Doug Kirkpatrick. We've looked at a variety of launch elevations, 20 degrees, 45 degrees. The Operations group had 75 degrees. Is there anything technically wrong with going straight up, MagLift straight up? We accelerate a 1.3 million pound vehicle straight up.

DR. BLOW: Does anybody want to take that one?

MR. TURMAN: I guess that kind of falls into the technology area. Yes, I think there are problems with trying to accelerate straight up. For one thing, one of the concepts, one of the operational advantages of MagLifter that we've been talking about is the horizontal integration of packages, and if you throw that away, now you're looking like a launch pad once again with vertical integration. I think there is a big advantage to going somewhere in the 30 to 40 degree angle elevation.

DR. BLOW: Could I ask, sir, why do you ask that question?

COL. KIRKPATRICK: The reason I asked that, from an operational standpoint, it would be nice to be able to take any azimuth. You know, start horizontal, accelerate up the tunnel vertically, then you could go any azimuth. Turn the vehicle to the azimuth that you want to take. It really makes it flexible.

DR. SIEBENHAAR: Maybe I can give the answer to his question.

DR. BLOW: Kindly identify yourself, please.

DR. SIEBENHAAR: Adam Siebenhaar. The reason it stays in orbit is horizontal, is parallel to the surface. Any component you have from the main direction is a total waste.

MR. TURMAN: Just to get out of the atmosphere, you want to go as straight up as you can, going out of the atmosphere.

DR. SIEBENHAAR: Well, you gain a little bit on your velocities.

MR. TURMAN: Right.

DR. SIEBENHAAR: And come up somewhere else.

MR. SULLIVAN: Ron Sullivan, Lockheed Martin. There is a trade to be made and this point is well taken. If you could get up to geo, if you had enough acceleration and delta  $v$  to get the potential altitude to geo, you wouldn't have much problem getting an orbital synchronization with a small delta  $v$ . The problem is that potential energy is equivalent to kinetic energy which is hard to come by, that's why this isn't working. Bottom line is, I think his question is well put. I think the vertical integration versus 45 degrees or 35 degrees is not that big of a deal if you were in a situation where you just come in on a horizontal position and you install the satellite or whatever it is you were trying to put in orbit, and I think technically the MagLift part is just one more extra detail that you have to overcome, so that should not be a big deal. The problem is bringing it up vertical. The whole advantage is to give you longer length or vertical velocity, so Adam's right, but you do get the trade and you do get part of that energy back as you start accelerating. Zero losses, X losses in a horizontal operation.

UNIDENTIFIED SPEAKER: And you have more customers with a better azimuth, flexibility.

DR. BLOW: Mike, did you have a question?

MR. HENNESSEY: Mike Hennessey, Intermagnetics. It's actually easier to do vertical from the MagLift standpoint, because your lateral forces are small, and you don't have the levitation problem.

DR. BLOW: Maybe separation would be easier.

UNIDENTIFIED SPEAKER: There's the power that's involved in here, too. You've got more Gs for propulsion and velocity. I'm assuming that just means

more electrical power to increase the magnetic. Is that too much? Is that over the limit? Is really my question.

MR. TURMAN: Well, that's probably another 30 percent or so in power. Now, what we're looking at scaling from right now is about a factor of five or something like that, scaling in power from where the magnetic propulsion technologies feels comfortable, so if your scaling has a factor of five or six or seven, it may not be that much of a technology step.

MR. HOWELL: Joe Howell, NASA Marshall. We ran the pyramid studies on this to launch with a pure rocket vehicle and that's one of the charts that John has been showing and the optimum angle for launch that we came up with is around 60 to 70 degrees. It drops off a little bit if you go straight up, and not a whole lot, though, and then it drops if you go -- veer hard on, it drops away. The optimum angle, just getting the mass to orbit, is around 60 to 70.

UNIDENTIFIED SPEAKER: For payload fraction to orbit, right?

MR. HOWELL: Right.

DR. SIEBENHAAR: The amount of payload basis?

MR. HOWELL: Okay. The amount of payload to orbit just based on launching at 600 miles an hour at 10,000 foot output, just looking at the velocity and altitude and varying angles, and the angle came out at about 60 to 70 degrees.

MR. CASSETTI: Do you know what the losses are taking the -- if you keep that setup to go into a polar orbit, you've got the track going to the south, let's say, and you want to now go to an equatorial orbit or launch to the east, do you know what the payload losses are for that?

MR. HOWELL: Okay. We ran some numbers on that also, and launching due east from like 33 degrees latitude, say, was putting up 39,000 pounds to orbit, if we went over to about 20 from that, plane change to about 20 degrees, it was about five, 6,000 pound loss in payload to make that plane change, and this was a purely rocket powered plane change, no lift to body effect at all.

MR. CASSETTI: 5,000 off 20,000?

MR. HOWELL: About 5,000 off of 39,000.

MR. CASSETTI: Of the 39,000?

MR. HOWELL: Right. Five to 6,000 off of the 39. We did not look going all the way to polar on there. That would be quite a number to go all the way to polar.

MR. CASSETTI: See, that's the problem we get into is you tend to -- there's a tendency to be two classes of satellites. Those that like to be in equatorial orbits and those that like to be in high inclination.

MR. HOWELL: Right.

MR. CASSETTI: And those are not mutually exclusive for this, but there's a big cost here.

UNIDENTIFIED SPEAKER: If you have an aerodynamic vehicle, particularly if you have a combined cycle or an air breather engine in there, there might be quite a bit of maneuvering ability which would help with the question that you had about being able to come to the full range. So a hybrid vehicle might be a good thing to look at.

UNIDENTIFIED SPEAKER: I'd like to add that 600 miles per hour, a relative cost in delta  $v$  feet per second is small in terms of air propulsion, air frame. We're talking about 5,000 to 39,999 is a small penalty. The real problem comes in is like typically when you have to dog-leg around Cuba or something like that, or polar orbit, you pay a penalty to do that, because your velocity time to do that dog-leg is high. And so, again, there's trades. If you're vertically launched and you come out at four or 5,000, 6,000 feet per second, then you have an inclination or not inclination, but a pitch angle problem, that is the flight path angle is more of a detriment than it is at 600 miles per hour, and you'd rather be down around probably 45 to 30 degrees is where the optimum trajectory point would be, but to make a plane change, 90 degrees is perfect, so that gets into some issues in terms of the best way to implement this technology.

MR. BLOW: Any other points to made? Yes, Gary?

MR. RODRIGUEZ: I'd like to suggest maybe a possibility for an evolutionary delivery might be able to bring in our schedules, and that would be considering that electromagnetics might be our ultimate objective, that we might simplify the track and simplify recovery from the crash inside the slot or the tunnel, by going with a straight rail, and then taking the sled or shuttle part of this thing, and putting like four big turbo fans on that thing, and then using it in the ground effect mode to move that thing, and just use a straight jet. I mean, you carry enough fuel on board to move this 100, 200,000 pound thing to try to get that exit velocity and then let it light-off the other side and come down the rail to decelerate, and it might speed up this whole process and we're not sitting here with commutators and armatures and everything else strung up and down miles and miles to alleviate us buying billions of dollars worth of storage and et cetera. You know, it may bring the economics to us and make the possibilities.

DR. BLOW: I may be missing something. Are you talking about steel wheels on steel rail, or shoes or something?

MR. RODRIGUEZ: No, I'm talking about ground effect on the rail itself by taking -- you've seen the carrier, you know how that works. By taking directed thrusts off of these things, pressurizing an air film underneath the carrier vehicle, and then using forward -- using thrust, conventional thrust, after-burners, whatever, on a couple of the engines to get the forward delta v.

DR. BLOW: What's providing the -- you said --

MR. RODRIGUEZ: Take a couple of the engines and just direct their exhaust gases.

DR. BLOW: You're getting both lift and propulsion?

MR. RODRIGUEZ: Right. And take a couple of after-burners to get forward, and it might just speed up the time line to get an evolutionary delivery underway. It would cut a lot of costs out pretty quickly.

DR. BLOW: Am I the only one who is not catching on to this?

UNIDENTIFIED SPEAKER: Is this a test vehicle you're talking about?

MR. RODRIGUEZ: No, it is just something we could use for a couple, three years until we can afford -- we hit that break even, make a profit point and then we can start a second bore and fill it full of electronics.

MR. TURMAN: I think I understand the question that you're raising there and it's one of how to get to the objective. What we have been talking about here is magnetic levitation, magnet propulsion. In the transportation industry, that was looked at previously, that's called an air cushioned vehicle. You use an air cushion levitate it. Now, that's going to have to be a million pounds of levitation, so it's probably a big pressure and quite a bit of power required there, then, rather than the magnetic propulsion, you hang enough 747 engines on that carrier to get it up to the same velocity as the 747. Doing it in the same sort of conceptual framework that we've been talking about here, keeping it on the ground or in tunnel, so that we're doing the same thing except using more conventional propulsion. I haven't run any numbers on that. We were talking about it a few minutes ago. The 747 doesn't accelerate in the same sort of distance that we're talking about here, so that's more than four 747 engines, that's probably ten or 15, I don't know what the number is, but I think it's a tradeoff that needs to be looked at, because that's an obvious question when we come with the strategic planning questions that were raised. When you go to a CEO, he's going to ask that question or somebody is going to ask that question

pretty fast. So once again, it's a question of doing a quick OPS decision to make sure that the framework we're talking about is the most efficient one. I think that probably what will come up is that you will need more thrust and more engines than you can easily get out of a set of jet engines to do it on a short time frame. A jet just doesn't accelerate at three Gs, but we may not have to accelerate at three Gs either if we get a long enough runway, so I think we need to look at that.

MR. RODRIGUEZ: Well, especially, I take it, it takes cost out of some capital items and puts them elsewhere, and I think also you eliminate, you reduce the cost per mile of this thing, so maybe you can afford at a lower cost to build a couple of more miles of it or so. Because the objective, as I see it, is not necessarily even to build a magnetic technology. What I see as the objective is low cost to orbit, and so I see things like this one to four percent gross liftoff weight is our payload, that sort of thing. If this is going to be a problem, we've got to work on those little numbers and get those in the larger numbers, two digit numbers, that sort of thing, and so it's like I don't want to see us lose our objective, which is to get to market quickly, turn a profit as soon as we can without getting crazy about it, and then we could work out an evolution delivery of even better technologies.

DR. BLOW: I know John Mankins isn't here, but he's talked about before about having I would call maybe not innovative, but maybe alternative concepts to get the job done that don't necessarily depend on the electromagnetic substances, so maybe that's, at least, one to put in a notebook and kick it around. Anybody else want to bring up another question altogether?

UNIDENTIFIED SPEAKER: My assumption here is that the tunnel costs are proportional to volume, which is proportional to the square of the radius, and I think your presentation was driven by the aerodynamic vehicle. Does this argue for some study on variable configuration? Variable means, it's very narrow through the tunnel and opens up to the air, or has that already been --

DR. BLOW: For air flow advancement you're talking about?

UNIDENTIFIED SPEAKER: Well, to keep the tunnel diameter radius small, but then once it leaves the tunnel, it needs to be aerodynamic.

MR. CHRISTIE: I think it needs to be looked at. I mean, the sensitivity is a dollar per cubic meter of soil removed or rock removed, that was kind of the number we used. So if you can reduce that, obviously then you'll reduce the cost. On the other case, we didn't have a tunnel. We had a cover, and then you may notice that the costs were cut in half, rough order of magnitude cut in half, so, yes, I do think we need to look at that.

UNIDENTIFIED SPEAKER: I guess that would be a technology issue.

MR. CHRISTIE: Yes. It's not so much an industry standard as with the gentlemen we had in the room. He had one number of a tunnel that was bored here recently. We used that and then we bounced it off of this recent cost estimate that's been kicked around, the tunnel at Berthoud Pass, and the numbers weren't that far off, so we just ran it through the mountain.

DR. BLOW: I'd like to ask a question myself, Ralph, does the shape of tunnel -- I've seen the schematics. It looks elliptical. Does that pose any kind of a construction, raw capital construction problem?

MR. CHRISTIE: We don't think so. I think Maynard and others thought, actually, the elliptical shape was better, was more efficient. Is that right, Maynard?

DR. SLAUGHTER: One boring will make almost a perfect ellipse.

DR. BLOW: In one pass?

DR. SLAUGHTER: Yes.

DR. BLOW: Gary, do you have a question?

MR. RODRIGUEZ: Yes, I was going to offer that maybe even if the vehicle is an air breather, that on the ascent phase borrowing something from one of the other speakers, that we want to get it out of gravity pull as quickly as possible, perhaps we don't even care to deploy the airfoils on the ascent phase. They stay entirely retracted until the descent face, and therefore, it would reduce the size of the bore that you need. You know, that it's ballistic except it's an air breather.

DR. BLOW: Wrap around surfaces?

MR. RODRIGUEZ: Not the aerodynamics system, only the pilot.

DR. BLOW: Any comment from the session chairmen on that?

MR. TURMAN: Certainly the swing wing aircraft design is something that you use, like an F-111 and its full swept-back configuration, and it pops back out when you're landing. I guess that technology is pretty well-developed. It's a question of reliability, making sure that you got the wings when you need them, though.

DR. SIEBENHAAR: If you have the wings, you might as well use them, otherwise they're just dead weight and the movement even heavier, so I don't see the logic in using anything like that.

MR. TURMAN: Well, what he is trying to do is trade off the initial tunneling cost and you would gain in tunneling cost, but you would lose in weight, so that's the trade off.

MR. RODRIGUEZ: If you get them out there on your ascent phase, you don't need them. They're just drag.

MR. TURMAN: I thought we needed them on the ascent phase for safety?

MR. RODRIGUEZ: Sure, but for safety you would employ them, if you have to.

DR. SIEBENHAAR: I think everybody agrees that if we have altitude and velocity that is going to be beneficial. We don't need to demonstrate that. What we need to demonstrate is how do we get to the G, okay, and if you want to go with a MagLift, that's what you have to demonstrate, otherwise you have missed the point.

MR. McALLISTER: Has anybody commented on the diameter necessary for the balloon?

DR. BLOW: The diameter necessary for what? I'm sorry.

MR. McALLISTER: The balloon for the rocket.

DR. BLOW: Post ignition?

UNIDENTIFIED SPEAKER: I don't feel that engine really should go in full thrust until you've gone past the axis.

DR. BLOW: Gentlemen, do you have a model of the ignition? I mean, is that a flexible point right now?

MR. CHRISTIE: If I can comment, we made the assumption that there were several hundred yards, if not more, behind the rocket or the acoustics and overpressure considerations. I mean, and when you normally launch a rocket, you've got a plane bucket, you've got things that are channeling all this overpressure and deluge of water and everything else, and we're setting this thing down in a shell and it's got no place to go, so we just recognize that that's an issue. We've got to leave some space behind the rocket and we're going to have to look at the acoustic overpressure issues, so that cannot be overlooked.

MR. CASSETTI: Also, the acoustics on payloads.

MR. CHRISTIE: On payloads, exactly.

DR. BLOW: Yes, sir?

UNIDENTIFIED SPEAKER: Why do you have to have a rocket on during this acceleration other than make the idle conditions, make sure they're operating?

MR. CHISHOLM: Well, the main thing we want is to get ignition just prior to release and verify that we've got ignition before we commit to a release from the cradle. If we don't get ignition, you know, we want to ride the cradle on down into abort mode without ever releasing. We don't need to go to full power I don't think, unless we get to studying it and we find out there's a potential failure mode in throttle. If there's a potential failure mode in throttle, then we have to reexamine it, but I think all we want is to verify ignition.

UNIDENTIFIED SPEAKER: Two points. You know, if you're a solid, it's probably a very, very small percentage of the times it's not going to ignite. Secondly, if it does ignite, whether it's a solid or a liquid, there's a finite possibility it's going to explode after it goes into full power. The bottom line is, is that to constrain in any significant manner at all the design of the tube or the housing system or external seems to be premature at this point in time, and furthermore, you certainly will not want to waste the rocket fuel that we've got, you know, accelerant, that's essentially for -- we want that for the delta v beyond it. So an idle condition if it's a liquid system, fine. Make sure everything is running so we're ready to go, but other than that, I don't know you need it. And as far as riding the rail on down, now you've got to take all this mass, which is, you know, several times what the sled is, and accommodate that with design of the recovery system.

UNIDENTIFIED SPEAKER: It's better than just throwing it out there across the wild blue yonder.

UNIDENTIFIED SPEAKER: Because you've got population out there.

UNIDENTIFIED SPEAKER: It's not going to go that far at 600 feet per second.

MR. CHISHOLM: Another thing, I admit it's an important consideration, but it's very bad public relations when we send them off and you fail.

UNIDENTIFIED SPEAKER: If it crashes.

MR. CHISHOLM: Yes, unfortunately it's business. You can be sure it would be in the New York Times.

MR. MUELLER: Don Mueller, Colorado Tech. There is another reason I think why you may not want to ignite the engine while it's on the guide rails. If you're

using MagLev, the clearances are not that large, and if the thrust axis is not aligned perfectly with the rails, you're going to generate side forces that may cause you to kiss the rails inadvertently, and, you know, you're going to have the same problem if you have an aerodynamic lifting vehicle also ride those rails, you're going to have the problem of containing the clearance on the MagLift system with unpredictable side forces.

DR. BLOW: Well, when you say small, you're talking about the lateral clearances?

MR. MUELLER: Well, I'm talking about the whole reason you're going to MagLev is to avoid bumping the rails, otherwise you go steel on steel, right? So what I'm saying, if you light an engine and its thrust axis is not perfectly aligned with the rails, you're going to generate side forces that you don't want and may not be able to handle.

MR. CASSETTI: The other aspect that you have is if you have a liquid fueled vehicle that's being accelerated down this track and it exits out the mountain, what is the first thing that is going to happen to it? It's going to decelerate pretty quickly because of drag. All the propellants are going to go rushing out away from the engine, so you've got to have a pretty complex way of keeping fluid flow to the engines and keep from adjusting vapor. That's a tough problem. So you've got to somehow moderate the acceleration provided by the rocket part to overcome the drag as soon as you hit the atmosphere or as soon as -- I should say, not as soon as you hit the atmosphere, you're going to be in it most of the time, but as soon as you stop accelerating with the magnetic carriage. With the carriage, as soon as you get off of that carriage, you're going to be sliding propellants from the front of the vehicle. Now, it's just the laws of physics, so you've got to have an extra complication on there unless you've got a way of positively accelerating off of that carriage with the rocket. More than the drag is accelerant.

UNIDENTIFIED SPEAKER: It sounds to me like you're making an argument for solid propellant.

MR. CASSETTI: There's another argument with solids, though, they tend to be dirty and people don't want them in their state or their tunnels.

UNIDENTIFIED SPEAKER: Some of them don't want them in our space ships.

MR. CASSETTI: So it's not an easy solution. In fact, in the early days of ICBMs, they destroyed a lot of ICBMs before they realized they had propellant slamming to the front of the tanks when they shut the engines off. So, you know, for safety and so forth.

DR. BLOW: Joe, is this kind of an open issue as far as Marshall is concerned?

MR. HOWELL: Yes, it is. But you certainly have to have a potent enough accelerator to overcome the problems when you clear the cap.

DR. BLOW: Sounds to me like there's a modeling challenge built into modeling this off-axis ignition possibility, is that something you do?

MR. HOWELL: Well, I don't make those disturbances, but the Holloman sled, they've got a vapor lock on there and it stays the thing, too. It's my understanding, they got these disturbances in their system that they design upon, and surely, we can have the feedback off of them before we want to go here, so I certainly think that's something that we can do.

UNIDENTIFIED SPEAKER: Certainly running this thing from horizontal to some angle as well, there's got to be hitting the rail as you go.

MR. HOWELL: Certainly.

DR. BLOW: Mike, did you have a comment?

MR. HENNESSEY: Yes. If the off axis is firing, it can be solved pretty easy at the end of the track. You can provide propulsion so that you have both levitation and propulsion from the top to hold it in a small tube for a few, I don't know, few hundred feet, and fire it there right on center, the propulsion system.

DR. BLOW: And lateral, you have lateral control, too?

MR. HENNESSEY: Yes.

UNIDENTIFIED SPEAKER: And I had a couple of points to make. One, asking an issue about that, I think that an added interest is the duty-up cycle and throttling and might be one thirty-second with 600 feet per second, 200 feet per second, quarter of a second or so, and I don't know what the throttle rates are on the turbine speed at full throttle on the rocket system. The second point is if you're at relatively high coefficient, you're coming off 600, 800 miles per hour, in 600 miles per hour, 800 feet per second or so, I doubt the drag is such that it's like slamming through a brick wall. It's going to slow you up, but I think you can account for that in the way you handle the propellants and in the positive displacement system and make sure --

MR. CASSETTI: You have to go to positive displays.

UNIDENTIFIED SPEAKER: For that start-up session, which is only a couple of seconds or so, that you can maintain the fluid positive displacement condition. A

solid would solve that, you know, all the ICBMs and Stealths ignite and do the things, same with all our tactile missiles.

DR. BLOW: What kind of penalty, if any, do you pay in propellant? I mean, are you saying --

UNIDENTIFIED SPEAKER: It's a matter of its going out inertly or displacement bladder or a separate small tank, or whatever, to assure that you have a positive displacement uninterrupted to the feed system of the turbines to the engine. You just have to account for that and I agree with Douglas' comment about that.

LT. COL. JOSLIN: Randy Joslin of Space Command. A similar question along the same lines. The hold-down mechanisms today for rockets that are launched statically off the pad, I'm not the expert on this, this is a question for the group, we don't need to be run up to near 100 percent and then verify that the engine's going and then let it go?

MR. CASSETTI: You mean like the solids?

LT. COL. JOSLIN: So if you were talking about a liquid engine, presumably one of the previously cited advantages of MagLifter was you would be able to make a decision to abort if you were not satisfied with the conditions of the engine. It sounds like maybe there's an issue here because you may be letting go of that. You may lose that flexibility if you're constrained to not being able to throttle up to a 100 percent before you're letting go.

UNIDENTIFIED SPEAKER: While you're on the rail?

LT. COL. JOSLIN: While you're on the rail.

MR. HOWELL: The consideration has been if you're doing 600 miles an hour, you could probably abort and stay on the guide rail, but if you're going with the faster vehicle, like a 1,200, we never even considered staying on the pathway there. We're going to launch when we get to that point whether we fire the engine or not.

UNIDENTIFIED SPEAKER: If you have flight capability on that vehicle, you might just plan on aborting by flying into a recovery runway. It's probably easier than trying to abort on the guideway itself.

MR. SCHENA: Ron Schena, Signal. I don't know if Marlowe wants to cover that one or not. There is one rocket car or vehicle that flies off the start, you know, it does its checkup in three and a half seconds and then when it flies up, it's looking good, and it throttles up, flies off the launch stand. It's not held down as the DCX. It's a concept that was proposed by McDonnell Douglas for Ford Aero,

the Delta Clipper operation concept. So there's a precedent for doing it the other way also, fly off and there could be other more simple mechanisms for possibly, not necessarily a hold down, but allow you to do the abort in that case.

DR. BLOW: My watch says we've got somewhere around five minutes to be right about on time. Are there any questions before we hear from the General?

UNIDENTIFIED SPEAKER: Something about the abort. If you're aborting the full contents, the aerodynamics are the same, but your ability to maneuver the vehicle is a lot different and your performance, so that would envision that you would have to have a quick way of getting rid of these sometimes nasty propellants, sometimes very nasty in terms of explosives. If they come in contact with some other subsystem that's burning something back there, it gives you your hydraulic power and so forth, and so I think it's a better idea, but the question is, what can you do or consider it?

UNIDENTIFIED SPEAKER: On the abort rail, I haven't seen quite what that looks like yet and I don't picture it in my mind very well, but we are going up this hill at 45 degrees or something like that at 600 miles an hour or close to it, we decide to abort, where's the rail for that abort?

DR. BLOW: Well, I've seen it. It's called a decelerator guide rail. That's the overt negative G and then down, and it's sort of ends there.

UNIDENTIFIED SPEAKER: Another mile or two?

DR. BLOW: Yes.

UNIDENTIFIED SPEAKER: It would be about the same?

UNIDENTIFIED SPEAKER: It's like turning off a roller coaster.

MR. CASSETTI: What's the lateral acceleration at the rollover?

UNIDENTIFIED SPEAKER: And for the passengers that are going up to the hotel in space?

DR. BLOW: Gentlemen, that's a tough issue, isn't it, that decelerator thing? That's going to linger for a while, I think, and the conceptual diagram that you see, it's easy to sort of tail off there, but --

MR. HOWELL: The conceptual diagram part, at 90 degrees we do not. So --

DR. BLOW: Now shouldn't there be some crossover from the Holloman effort, though, in that respect? Because they're going to have to slow down. Although, it's horizontal, they're going to be slowing down at much higher speeds.

MR. HOWELL: I think there's probably a lot of things that Holloman is doing that we can use in our design, certainly.

UNIDENTIFIED SPEAKER: Quick question for the Air Force representative, and that is on potential future tac sats, you know, Martin Marietta in the past has built systems that are done launched and so they've got thousands of Gs on electronics, sensors, seekers and so forth. The bottom line is, possibly it would make some sense to look at a trade study, future requirements in terms of sensors in space and what it takes to harden them to higher Gs and follow up on that, then use your magnetic system to really give you an advantage in terms of total energy. In other words, get up to ten, 15,000 feet per second at higher payload with much smaller packaging, but a very simple rocket system. I'll have some stuff that part of us with Aero got a few years ago, that I think would give extra incentive considering this technology developing. I think it gets back to what Jeff Samella said yesterday about assuring the access in space and vulnerability, et cetera.

DR. BLOW: Mike, did you have one more question?

MR. HENNESSEY: Just on the vertical propulsion, there is a problem and that is recovery in that we have to build some kind of a roller coaster out of the tunnel down to, if you wanted to maintain a carriage, otherwise you have to make it and not have a carriage. If you want to recover the rocket, you have to build something out of the hole.

UNIDENTIFIED SPEAKER: Larry, I'd like to make a comment on the question about hardening the packages for smaller satellites and sensors into space. We looked at that as a tradeoff on the other end of the curve from what we're talking about with MagLifter. You can gain quite a bit from the electromagnetic launcher if you are willing to go to high Gs. High Gs being like a couple of thousand, in that range, but that is down below what the gun hardened electronics have already obtained. So that you can get payload performance improvements like ten, 15, 20 percent pretty easily by going up to very high velocities, so that's a good approach to take, but then you also have to worry about aerodynamics, the aero-thermodynamics of the high velocities.

DR. BLOW: Sure. I think that's going to do it. Thanks very much, gentlemen. I appreciate it.

## PRESENTATION BY DR. NEVILLE MARZWELL

### NASA JET PROPULSION LABORATORY

DR. BEER: It gives me great pleasure to introduce Neville Marzwell, who has volunteered to assist us in the strategic planning effort, and he has got five minutes to do now, because he's got an airplane to catch. So the next time we get together, we're going to adjourn earlier, so that we don't have people having to race for airplanes. Neville?

MR. MARZWELL: Thank you. What you have here is to succeed and the best method to succeed is to remember errors of the past, where we did go wrong. What have we learned from the past? I'd like to start with an example.

We invented in this country the composite materials, but you never made a cent out of it. The Japanese made \$6.4 billion a year out of using this and making fishing poles, okay? So we have to learn here that when we invent something, we're going to use it.

So what it takes to succeed is, basically, we need to have a focused vision. We need to know specifically where we are. We need to have a fair assessment of our capability, our abilities and reality of the environment of today. I really don't feel that the government is in the mood for the next two to three years in jumping up and having big new starts. We have to be realists.

Money does not recognize borders or boundaries. Money goes where profit exists, so I don't feel there is a problem in getting capital investment. The problem is us engineers coming up with a concept that is profitable, a market that is profitable.

Now, the next question is, what do we have? Okay. We have individuals that are capable engineers, but we have to be redesigned to come up with a concept that is focused, that is narrow, that is customer-oriented, that is profitable. We need to really do public relations with the government. We have a tremendous multi-billion infrastructure in this country with magnetic superconductors that really are being degraded. In fact, at request, in my judgment, the government will be eager and willing to give it to us, just give it, because they are being degraded fast, so this can be the seed from which to grow.

We need a vision that is founded. The words here are founded and focused. What, therefore, do we need. We need a near term goal that is realizable and credible. We need a constant focus on realism. We cannot go into a hallucination mode of big dreams. We need a small dream with small cost, with small range, achievable within a short period of time, and I will make

recommendations at the end. We need to assess and understand the market, the customers, the state corridors. We need to serve their need. We cannot count on them spending money year after year without seeing some returns now. We need an organization with specific goals. We need all of us to be integrated into what Chrysler did in the Viper program. Operation engineers, technologists, cost analysts teamed together in a Tiger team to really use the best of us in coming up with an approach.

We need a perception. We need to be perceived and we need an image. An image that says that we know what we are doing. We are credible. We can deliver profit. We are a national entity.

We need a process. The process is based on trade analysis between the various concepts, the various technologies. We need to identify the threads and the opportunities, and we need to select that jewel in the sand that is near term goal achievable, low cost, that can give us the credibility and fuel the thrust for future development and future effort.

We cannot run out of steam at mid course. We need to achieve the critical mass in funding and capabilities and resources. We need a support base. The support base is the public, the government, the industry, the education. We need to say that this has enough enthusiasm to stimulate the people to understand engineering to get turned on.

We need to become the first, again, like the Mars program, like the Atlas program, like the Pioneer program.

The government cannot be counted on. I think for the near two to three years if not four, we cannot count -- we really cannot count on government for technology money. We need to develop an implementation plan and the functional plan that has visibility, many minds speak for and risk, reasonable risk for high payoff, and we need, basically, to take a close look, assess, make an effort, evaluate the reaction and correct it. We cannot afford any mistake. The problem is -- no pitfalls. The effort is big, but the effort is doable and achievable. The payback is also high for us engineers and for the country.

We need to magnify that to the public. We must have their support. We must have their enthusiasm. One of the ideas is to make a one-page letter every three months. We need to interact closely with the media. We need to interact closely with the business. Engineers talking to engineers is not going to make the dollars. We need a leadership that is striving to please few, because we cannot please everyone.

Therefore, what is the recommendation? By priority, we need a trade analysis between the concepts, the various technologies, the various operations, and come up with that jewel in the sand, that if we stick around it, is doable in short years. People are not patient. If we cannot deliver something within a reasonable time, a demo, they're going to lose interest. It's going to die.

We need a center for information. Each one of us has a lot of information, but we need all that as a ministry of information among us that will have all the information such that we do not waste money and effort reinventing the wheel. We need to identify the next step. And that is the jewel that we have to find.

Where do we go from now? What is that next step that really can get political, business, social, economical strategy behind us? Thank you.



## BREAKOUT SESSION SUMMARIES

### Breakout Session #1 -- Critical Technologies and Research Issues

The Critical Technologies and Research Issues panel based their assessment on a series of constraints and assumptions including using a pure rocket vehicle, as opposed to an aerodynamic vehicle; employing X-33 technology (leveraging X-33 investment and programmatic heritage); an upgrade path to larger vehicles; an assumed 5,000 lb. payload to polar orbit resulting in a 'big scale' (700,000 lb.) total system; and a significant and challenging infrastructure development. It was noted that a winged SSTO vehicle (example offered by Aerojet) could significantly increase the payload mass fraction, or conversely, significantly decrease the gross liftoff weight (GLOW) requirement.

Based on the pure rocket vehicle constraints and assumptions, the panel determined that the MagLifter concept vehicle was viable. The following conclusions and technology issues were identified:

- The orbital vehicle will have a payload of 1-4% GLOW
  - There is a need to better understand vehicle issues and propulsion technologies.
- MagLifter and MagDriver are different tasks and technologies
  - "Lift" is insensitive to scale
  - "Driver" is sensitive to scale
  - It is imperative to isolate and understand these differences and the resultant implications
- The technologies for the infrastructure may be a function of scale
  - Infrastructure and vehicle interactions are critical to understanding and implementing the MagLifter concept
- Programmatic interactions must be understood and managed
- It is critical to "pick the right size" based on both market and infrastructure considerations
- Subsystem risks must be evaluated and application technologies demonstrated

## Breakout Session #2 -- Development and Integration

The Development and Integration panel identified five (5) major topic areas for discussion and assessment: 1) Market; 2) System Requirements; 3) Prototype System; 4) Tunnel; and 5) Flight Vehicle Development and System Integration.

The *Market* will drive both the schedule and the risk. Potential customers will require both reliability and low relative cost. The current mini-business plan addresses one near term customer that drives the MagLifter program schedule and cost. Will this customer (Teledesic) devote sufficient business to MagLifter? Other market-related issues to be resolved include identifying other post-RLV target customers, payload capability with other launch systems, determining if there is a benefit in addressing non-launch user technologies. Also to be addressed is the issue of failure/back-up coupled with launch rate requirements -- is there a need for two launch systems?

In the area of *System Requirements* the panel determined that these are still being defined and are the critical next steps in the MagLifter development process. Some major issues identified relative to the development of system requirements (and "flow-down" to element, subsystem, and component requirements) include design life (system and element), payload(s), evolutionary vs. revolutionary growth/upgrade, RMA (reliability/maintainability/availability), and failure issues and back-up approach.

The major point of concern related to the *Prototype System* is the definition of the objectives for the prototype. Specifically, the panel defined the following topics for further study/definition: requirements for the prototype; technical demonstration vs. value-added operations system; acceptable projected costs, schedule, risks to be associated with the prototype; design issues such as identification of the driver or "forcing function" for a demonstration; and determination of the level of technical "scalability" to the final function. Additionally, the issues related to results need to be addressed. These include: whether to include a tunnel or use existing other facilities; location for the demonstration; overflight; component vs. total system demonstration(s); purpose of the demonstration related to 'who & why' for funding (the demo funding may differ from the operational system funding, i.e. as a technology proof-of-concept vs. early stage of operational system; and alternative uses of the prototype.

The *Tunnel* issues centered around schedule, maintenance, location, and growth capability for the launch facility. These included questions related to whether a tunnel (i.e. a bored tunnel in a mountain) vs. a 'notch' (cut-and-covered, or uncovered along the side of a mountain) was the appropriate form for the launch facility; proximity of recovery/landing site for reusable launch vehicle; rocket vs. aerodynamic vehicle impacts; and transportation and logistics support.

The fifth major topic area covered the *Flight Vehicle Development and System Integration*. The panel determined that schedule and cost considerations for development of the flight vehicle, the definition and development of the other system elements, and the overall system integration process were not sufficiently understood and required significant study, in both technical and programmatic terms.

Finally, the Development and Integration panel concluded that the concept was viable, however, there are several issues to be addressed relative to an optimistic, single-user driven schedule. There needs to be effort dedicated to a stringent assessment of technology readiness vs. risk and the resultant schedule impacts; the need to clearly and comprehensively define system, element, and component level requirements early on; and the performance of a set of critical trade studies, such as exit velocity, weight vs. speed, manned vs. unmanned, and vehicle type; as well as those that are derived from addressing the topics detailed above.

### **Breakout Session #3 -- Construction and Engineering**

The Construction and Engineering panel consisted of a balanced and broad spectrum of organizations and focus areas: E/A and construction firms with focus on engineering design, construction, and operational systems; government agencies with a system/market/programmatic focus; higher education (academia) with a systems engineering and feasibility support focus; mining firms with focus areas in geology and tunnel technology; and geotechnical/environmental with a siting focus.

This panel addressed four areas: technical feasibility; economic feasibility; programmatic feasibility; and open issue definition. To address these areas the panel developed a set of assumptions and groundrules and applied them to two theoretical cases based on vehicle style (ballistic vs. aerodynamic), facility descriptions (size, inclination, tunnel type), and system elements included in the assessment. These two cases are summarized:

#### **CASE I:**

- 40-50 degree inclined;
- 10 meter tunnel bored in bedrock; and
- a ballistic, 3 meter RLV with vertical landing capability

#### **CASE II:**

- 20 degree inclination;
- 37 meter diameter 'cut-and-cover' tunnel with adjacent (<2 miles) landing site; and
- an aerodynamic, 30 meter RLV

(Both Cases I & II assumed SMES feasibility and externally supplied, downrange tracking compatible with existing facilities, a viable market to support FSD, and a 5,000 lb. payload-to-LEO capability.)

Support and personnel facilities and investment scenarios/considerations were not considered in this initial assessment.

Technical feasibility for each case was assessed, and the conclusions were: a 10 meter tunnel was feasible assuming acceptable geology (igneous/metamorphic rock); the 'cut-and-cover' option, while not insensitive to geology, was less sensitive than the bored tunnel option to specific geologic conditions.

- High maintenance issues were identified such as dewatering, wall maintenance, and corrosion/weathering issues however, solutions to these issues were available.
- Siting for the facility was identified as a potential major issue, specifically, finding an area less earthquake prone would be desirable for construction and maintenance. Finally, lining material that satisfies overpressure, acoustic, and heat considerations was identified as a topic for investigation.

Economic feasibility analysis favored Case II, predominantly due to the life cycle cost implications of the bored vs. 'cut-and-cover' tunnel architectures. However, both cases exceeded the projected costs in the initial mini-business plan.

The programmatic feasibility assessment addressed activities ranging from performing a comprehensive feasibility study through full scale development, including a contingency margin. The panel determined that a target time span (incorporating as much parallel effort as possible) would be 5.5 years from NTP/ATP to ILC.

The Engineering and Construction panel identified three major areas of open issues that need resolution to allow progress toward site/facility design. These were: power requirements and source; definition and validation of the market; and a better definition of the type and use of facilities (for example, a dual-use, government-civilian capability). The panel concluded that a feasibility study and market analysis should be performed as soon as possible to validate initial MagLifter concepts and options.

#### **Breakout Session #4 -- Operations**

The Operations panel concentrated on the critical issue for an inland launch -- overflight/range safety. The panel employed a series of Instantaneous Impact

point traces based on potential MagLifter flight azimuths (from a Colorado launch site) and developed a set of typical range safety analyses to assess the range safety/overflight issues for the MagLifter concept.

Based on these analyses, the panel determined that inland launch safety is a problem, but that a work-around could be developed for relevant issues, and that this effort should be the first priority for a comprehensive study. The panel determined that there are two approaches to address this issue -- range layout and casualty expectancy. The panel noted that launch range safety casualty expectancy algorithm differs from the algorithm currently under investigation by the DoT, thus enhancing the conclusion that an investigation into DoT/FAA airport criteria should be performed.

Other major points/issues related to overflight include: how to obtain valid and applicable reliability numbers (increasing '9s' is costly); and whether the eastern launch trace requirements for lower casualty expectancy will drive azimuth options and the related impacts. The panel also determined that there is a need to better identify and understand failure modes and to determine flight termination modes and criteria. Also the panel addressed issues relative to prototype/demonstration siting to support range testing.

The Operations panel identified several operations, issues to be considered. These included:

- Environmental impacts on operations such as:
  - Weather
  - Launch produced shock wave
  - Single launcher vs. dual systems
- Maintenance requirements:
  - Servicing
  - Refurbishing
  - Upgrade
  - Alignment
- Licensing/certification (DoT)
- Personnel issues such as
  - training
  - certification
  - quantity
  - type
- Reentry/landing sites
  - location(s)

-- instrument flight conditions

- Transportation and handling/logistic support

In summary, the Operations panel identified several issues, with overflight being the most critical; however, none of these considerations appear to be insurmountable given the appropriate effort to 'work' the issue.

### **Breakout Session #5 -- Implementation Plan**

The final of the five breakout sessions was the Implementation Plan panel. This group addressed issues concerning the MRC organization, critical programmatic concerns across all technical areas, investment and risks, public relations, and implementation approaches. The panel investigated the history of similar technology projects and proposals as the basis for their assessments.

The panel proposed an amendment to the MRC bylaws 'organization chart' to emphasize areas for infrastructure, legal/risk management, the environment, and MagLifter external interfaces. The panel determined that, for private investment, return must be commensurate with perceived risk, thus identifying some related issues such as perceived technology risks, political risks and incumbent delay, equity return, and need for definitive revenue projections.

In addition, the Implementation Plan panel identified a series of critical issues. These included: government assistance relative to assets transfer (land, orbits, etc.) and incentives; technical risk reduction approaches including the concept for and sizing of a prototype, the demonstration of 'scalability,' cost and schedule projections; and an ardent risk assessment program. This panel also addressed environmental issues, including overflight and launch abort considerations. These last two issues drove a preference for an aerodynamic vehicle configuration.

A major set of issues for this panel were those related to legislative and policy concerns. The panel addressed the need for enabling legislation (at all levels), the relationship to regulatory agency/agencies, considerations for liability limitations related to both public and customers, and safety issues. In addition, there were several market-related policy issues discussed by the panel: the need (or desire) for an 'anchor tenant(s),' government (DoD, NASA) or commercial or both; the need for an incentive program for long term commitments; and the market education that MagLifter is an application of a mature technology; and the need for an effective public relations program that emphasizes safety, economic benefit, and international competitiveness.

Finally, this panel identified the need to explore and exploit spin-off technologies, applications, and benefits as the MagLifter program will have to 'stand on its own' for ROI and technology transfer benefits proven as commercially viable.

## **BREAKOUT SESSION CONCLUSIONS AND RECOMMENDATIONS**

The five Breakout sessions described above were held in parallel. Although there was a roving 'ambassador' that visited all panels and several panels had 'ambassadors' to each other, the conclusions and recommendations were predominantly developed independently. There appeared to be a set of common themes that evolved from these sessions. The driving themes are summarized below:

- The MagLifter system is technically feasible and viable, although probably not quite within the projected cost and schedule scopes;
- Market analyses and feasibility studies need to be done immediately to define the market potential and risks;
- Several trade studies need to be performed in the near term related to vehicle type, facility configuration, and system configuration that incorporate inland range safety/overflight, technological and programmatic risk/feasibilities, internal and external interfaces, and growth scenarios;
- A clear and comprehensive understanding and statement of the market, concept and system requirements is needed soon;
- The prototype/demonstration(s) needs to be defined in terms of program goals and must be 'scalable' to the operational system;
- Public relations, government involvement, investor/customer relations, and associated/spin-off technologies need to be investigated and developed to make MagLifter a reality; and
- A disciplined, in-depth, cohesive analysis and development effort with a long-term, total system life orientation is critical to a successful near-term implementation of the MagLifter program.



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