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ORBITAL PAYLOAD RECOVERY

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Abstract

The growing focus on orbital manufacture and associated experimentation highlights an increasing need for reliable, low cost recovery of orbital payloads. Simplistic recovery operations and vehicles designed for refurbishment and reuse can provide this desired economy. Based on prior operational experience and present conceptional thinking both are immediately feasible.

With the accelerated commercial booster development now in progress, the operational facets of such programs remain the only significant cost elements still requiring definition and resolution.

This paper will describe the range of vehicles anticipated for such operations, the economies effecting their operation and restrictions and limitations they impose on planned payloads. It will further discuss the operational issues which require resolution and recommend respective roles of government and the private sector relative to these functions.
INTRODUCTION

- Projected growth in orbital manufacture demands versatile, low cost product recovery systems.

- Refurbishment and reflight provides requisite R/V economy.

- R/V Design compatibility with companion bus provides versatility without restricting design to specific payload accommodation.

- Trade off will generally favor recovery over remote monitoring and orbital abandonment of equipment.

- Efficient ballistic reentry will impose some restrictions on payloads which must be accommodated.

- Operational considerations pose major unresolved questions.

- Identification of Government versus private sector participation is critical to commercial space progress.
ECONOMIC CONSIDERATIONS

- Expendable Launch Vehicle (ELV) cost will dominate any anticipated commercial space operation.

- Where payload requirements demand a companion bus, its orbital abandonment with associated equipment could be a substantial cost element to be charged against the value of the payload.

- Reuse of the reentry/recovery system minimizes its contribution to program costs, tempered by refurbishment expense and total useful life.

- Low cost reentry/recovery will also favor recovery in situations where remote monitoring and orbital abandonment of equipment is an option.

- Major unresolved cost elements in projected endeavors involve operational considerations including:

  - Launch site utilization
  - Orbital Tracking
  - Command/Communication
  - Recovery Site selection and development
    - Refurbishment facilities
    - Logistics
  - Operational Restraints

- Insurance Coverage
CHEOPS-611 ORBITAL RECOVERY VEHICLE

- PAYLOAD ENVELOPE
- FUEL TANKS
- OXIDIZER TANKS (TYPICAL BOTH SIDES)
- ANTENNA, 4 PLCS
- RETRO ROCKET (OFFSET)
- CONTROLLABLE GLIDING PARACHUTE
- DROGUE CHUTE
- SINGLE POINT MOUNTING ATTACHMENT
- I.R. HORIZON SENSOR (2 PLACES)
- SPIN/DESPIN NOZZLE, 2 SETS
- ATTITUDE CONTROL THRUSTERS (4)
- PAYLOAD SUPPORT STRUCTURE
- PRESSURE TANK
- FIELD JOINT FOR FRONT END
- FOREBODY (NON-SEPARABLE HEATSHIELD)
DEORBIT WT.: 163 LBS.
R/V WT.: 133 LBS.
BALLIST. COEFF.: 95 PSF
STATIC MARGIN: 7%

DEORB1T TIMER

SPIN SYSTEM
GAS TANK

A.R.C. MARC 20
SERIES
SOLID ROCKET

EXPLOSIVE NUT (2)

SPIN NOZZLE (4)

CHUTE DEPLOYMENT
MORTAR

LOAD: 50 IBS.
11" DIA X 6" DP.
VOL.: 275 FT³

FIELD JOINT

HEATSHIELD
1 THK G.E. I.C.M.
OR EQUIV.

BATTERIES

RETRACTING ELECT. I/F
CONNECTOR

SPHERE

R/V MOUNTING
ADAPTER & DEPLOYMENT
SYSTEM

- PRIMARY I/F ATTACH.
AND RETRACTING R/V
ACCESS "CHASE"

PROGRAMMER

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# Table 1

## Orbital Payload Recovery Vehicle Comparison

<table>
<thead>
<tr>
<th>Physical/Performance Parameters</th>
<th>&quot;CHEOPS 64&quot;</th>
<th>&quot;Deliverer&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shape</td>
<td>Blunt Sphere/Cone</td>
<td>Spherical</td>
</tr>
<tr>
<td>Size</td>
<td>64 in. Base Dia.</td>
<td>16 in. Dia.</td>
</tr>
<tr>
<td>Total Weight</td>
<td>2175 lbs.</td>
<td>163 lbs.</td>
</tr>
<tr>
<td>Reentry Weight</td>
<td>1968 lbs.</td>
<td>133 lbs.</td>
</tr>
<tr>
<td>Payload Weight</td>
<td>1150 lbs.</td>
<td>50 lbs.</td>
</tr>
<tr>
<td>P/L Mass Fract.</td>
<td>0.53</td>
<td>0.31</td>
</tr>
<tr>
<td>Ballistic Coeff. ( (\beta) )</td>
<td>138 psf</td>
<td>95 psf</td>
</tr>
<tr>
<td>% Reuse</td>
<td>85% Est.</td>
<td>40% Est.</td>
</tr>
<tr>
<td>Debris</td>
<td>None</td>
<td>Deorb. Module</td>
</tr>
<tr>
<td>Term. Descent</td>
<td>Controlled Chute</td>
<td>Controlled Chute</td>
</tr>
<tr>
<td>Pref. Recov. Site</td>
<td>Land</td>
<td>Land</td>
</tr>
<tr>
<td>Est. Develop. Time</td>
<td>30 months</td>
<td>18 months</td>
</tr>
<tr>
<td>Est. Develop. Cost</td>
<td>$3.0 M</td>
<td>$500 K</td>
</tr>
</tbody>
</table>
Gravity Gradient Boom
Position Sensor
Solar Cells
Deorbit Module
Antenna
"Cansat" Satellite
"Deliverer" R/V

"Cansat"/"Deliverer" Orbiting System Configuration
DELIBERER

Deorbit Sequence

- Orbital System
- R/V Separation & Spin up
- Spin Stable R/V
- Retro Fire
- Reentry Orientation
- Reentry Module Separation
- Deorbit Module Separation

Fig. 4
"DELIVERER"
Controlled Terminal Descent And Landing Sequence
PAYLOAD RESTRICTIONS AND LIMITATIONS

Mechanical Loads

- Reentry deceleration = 7.0 - 8.0 G's (Low beta reentry).

- Launch and Ascent - Booster dependant but occurs prior to P/L system activation and product presence.

- Parachute deployment - Controllable

- Landing impact - Controllable

- Load tolerance limit is that level beyond which critical elements cannot be restrained, supported, encapsulated, etc.

Spin-up Environments (Spin stabilized booster stages or deorbit retro fire)

- Centrifugal forces due to rotation about longitudinal axis.

- Requires spin balancing at initial system assembly and maintainence of that balance throughout all spinning vehicle functions.

- "Deliverer" type vehicle is spin stabilized at separation from companion satellite to provide deorbit retro fire pointing.

- "CHEOPS" type vehicle has autonomous 3 axis attitude control, spin balancing not required in its normal operation.

Temperature

- Sources: - Solar impingement
  - Payload Output
  - Thermal soak from reentry heating

- Internal vehicle temperature due to natural environments can be limited to moderate levels and variations by Passive thermal control (External coatings and internal insulation).

- Precise temperature control of sensitive payloads is best controlled locally as part of the payload function.

- Rejection of excess thermal energy generated by the payload is similarly a payload function to be accommodated by the orbital vehicle system.
PAYLOAD RESTRICTIONS AND LIMITATIONS (Cont.)

Communication, Command and Control

- Primary R/V deorbit and recovery functions require orbital tracking but minimal command from the ground.
- Varying levels of communication can be provided to accommodate payload requirements at commensurate degrees of cost and complexity.
- Real time data gathering should be limited to that which can be acted upon in real time.
- Diagnostics and scientific curiosity are best served through recorded data recovered with the payload.

Ancillary Equipment

- Ideal Payload - Self contained, minimum interaction with orbiting vehicle other than mounting interface.
- Companion bus concept will accommodate broad spectrum of ancillary equipment for more demanding payloads.
  - Solar array power supplies
  - Radiator panels
  - Process control electronics
  - Etc.
- Orbital abandonment of bus relegates lower cost expendibles to bus mounting where feasible.
**SIGNIFICANT OPERATIONAL ISSUES**

**Orbital Tracking**

- Precise vehicle orbit is mandatory for accurate deorbit and pre-planned recovery operation.
- Global tracking networks in place under direction of governmental agencies.

**Communications**

- Limited communication with orbiting vehicle is required for set up of deorbit procedure.
- Communication for extensive monitoring, command and control is highly probable for the more sophisticated payloads.
- Similar to tracking, global satellite communication networks are in place under direction of the federal government.

**Landing Sites**

- Several international sites are currently showing interest in hosting an operational "Space Port".
- Site selection is national in scope and involves several crucial considerations.
  - Debris impact
  - Air Line Traffic Compatibility
  - Overflight
  - Orbital Track Compatibility
  - Landing Operation Compatibility/Special Facilities
SIGNIFICANT OPERATIONAL ISSUES (Cont.)

Recovered Payload Processing and Logistics

° Provisions for removal and special handling of orbital payloads will frequently be required immediately after recovery.

° Special environmental conditioning and control facilities may also be required for recovered payload accommodation.

° Provisions for refurbishment of recovery system elements for reflight will be a major facility cost driver.

- At recovery Site

- Return to Manufacturer

° Transportation and Logistics associated with both recovered payloads and vehicle reuse will influence operational economics and site location.
RECOMMENDED ROLES - PRIVATE SECTOR/GOVERNMENT

Private Sector

- Design, develop and build commercial launch systems.
- Design, develop and build commercial orbital payload accommodation and recovery systems.
- Develop commercial and associated experimental payloads and their integration into companion orbital recovery systems.
- Establish and conduct required testing on above systems.
- Plan and conduct launch, orbital and recovery operations on all commercial space programs.
- Plan, direct and conduct post recovery payload handling and processing.
- Plan, direct and conduct orbital recovery system refurbishment for reuse.

Government

- Provide use of existing launch and test facilities to commercial operators on a non-interference, equitable cost basis.
- Provide use of global tracking and satellite communication networks to commercial operators on a non-interference, equitable cost basis.
- Designate, develop and operate recovery sites for use by commercial operators.
- Provide for the interests of U. S. commercial space operations in all matters involving global interaction with other nations.
- Favor use of commercial operations over parallel development for national space activities where feasible.
- Provide federally subsidized insurance to commercial space operators for the initial phases of development of the industry.
SUMMARY/CONCLUSIONS

- Dawn of a new Industrial surge.
- Ultimate magnitude is unpredictable at this time.
- International interest is obvious and formidable competition is developing.
- U. S. still has significant advantages.
- Beware the Wright Brothers syndrome.
- The technology is in place, the skills are available, the lessons of the past are clear.