

---

The Space Congress® Proceedings

1990 (27th) 90's - Decade Of Opportunity

---

Apr 24th, 2:00 PM - 5:00 PM

## Paper Session I-C - Low Gravity Investigations on Suborbital Rockets

Francis C. Wessling

*The University of Alabama in Huntsville Huntsville, Alabama*

Charles A. Lundquist

*The University of Alabama in Huntsville Huntsville, Alabama*

Follow this and additional works at: <https://commons.erau.edu/space-congress-proceedings>

---

### Scholarly Commons Citation

Wessling, Francis C. and Lundquist, Charles A., "Paper Session I-C - Low Gravity Investigations on Suborbital Rockets" (1990). *The Space Congress® Proceedings*. 4.

<https://commons.erau.edu/space-congress-proceedings/proceedings-1990-27th/april-24-1990/4>

This Event is brought to you for free and open access by the Conferences at Scholarly Commons. It has been accepted for inclusion in The Space Congress® Proceedings by an authorized administrator of Scholarly Commons. For more information, please contact [commons@erau.edu](mailto:commons@erau.edu).

**EMBRY-RIDDLE**  
Aeronautical University™  
SCHOLARLY COMMONS

## Low Gravity Investigations on Suborbital Rockets

Francis C. Wessling\*  
Charles A. Lundquist\*\*  
The University of Alabama in Huntsville  
Huntsville, Alabama

### Abstract

The Consortium for Materials Development in Space has initiated two series of suborbital rocket missions to promote goals of the NASA Office of Commercial Programs. The broad objectives of the new missions are twofold: 1) to accomplish materials and biotechnology investigations in microgravity and 2) to stimulate the commercial rocket industry in the United States. The first series, designated the Consort missions, provide six to eight minutes of microgravity. Their launch and recovery operations are performed at the White Sands Missile Range in New Mexico. A Consort 1 flight occurred on March 29, 1989. All rocket and payload systems operated successfully. A Consort 2 mission occurred November 15, 1989. Consort 3 is scheduled for May 1990. The second series is designated Joust. It will provide 13-15 minutes of microgravity. Joust 1 is scheduled for launch in November 1990 from the Eastern Test Range in Florida. The Starfire rocket that launches Consort missions is a two stage vehicle. The Prospector rocket for Joust is a single stage vehicle.

### Motivation and History

Suborbital rockets provide free-flight opportunities for materials, biotechnology and similar investigations. In the spectrum of microgravity facilities, such rocket flights fill a niche between parabolic aircraft flights and satellite missions.

From 1976 to 1981 the United States National Aeronautics and Space Administration (NASA) provided scientific investigators with opportunities to fly experiments on 10 suborbital Space Processing Applications Rocket (SPAR) missions.<sup>1</sup> These flights were managed by the Marshall Space Flight Center for NASA. The SPAR program was completed as use of the Space Shuttle began. Other nations have established rocket programs with similar objectives.

Starting in 1988, to support the goals of the NASA Office of Commercial Programs, new suborbital missions were initiated. The effort is managed by the Consortium for Materials Development in Space (CMDS), with headquarters at the University of Alabama in Huntsville (UAH). This Consortium is one of the 16 Centers for Commercial Development of Space (CCDS), each of which has NASA and industrial sponsorship.

The broad objectives of the new suborbital missions are twofold: 1) to accomplish materials and biotechnology investigations having commercial value and 2) to stimulate the commercial rocket industry in the United States. For the first objective, the rocket payloads are assembled from

---

\*Professor, Department of Mechanical Engineering, Member AIAA, Associate Director, Consortium for Materials Development in Space

\*\*Director, Consortium for Materials Development in Space

instrumentation prepared by several of the CCDS's and by industries having joint agreements with NASA. To advance the second objective, the Consortium asked industries to propose commercial rocket services for two series of suborbital missions, designated Consort and Joust. The launches are licensed by the U.S. Department of Transportation.

Two joint industry and university teams are established to implement the Consort mission series and the Joust series, respectively. These capabilities are now available not only to launch and recover experiments for CCDS objectives, but also to sell microgravity flight services to other U.S. and international users.<sup>2</sup>

### Consort Program

#### Starfire Rocket

The performance of the two-stage Starfire I rocket and recovery systems selected to carry the Consort payloads is somewhat greater than the rocket that launched the earlier SPAR payloads. The Consort experiment sections have the same diameter (0.44 meters) and similar total length as SPAR sections, but the additional performance can provide either a heavier payload or a longer time in microgravity. Figure 1 shows the Starfire I performance.

Space Services Incorporated of Houston, Texas provides the integrated Starfire rocket services. The spin-stabilized vehicle is based on a Thiokol TX 664-4 booster motor and a Bristol Aerospace Black Brant VC sustainer motor. The vehicle uses a SAAB S19 guidance system, a Physical Science Laboratory telemetry system, a Space Vector Corporation rotation rate control system and a Bristol Ogive Recovery System. The maximum acceleration experienced is about 11 g's during launch and 20 g's on reentry. The payload is despun after rocket separation.

The Starfire I launches are at White Sands Missile Range, New Mexico. The flight apex is about 300 km and impact is about 80 km down range. The payload descends by parachute for recovery on the ground.

#### Consort Experiment Payloads

The Consort experiment payload has three cylindrical sections assembled end-to-end.<sup>3</sup> The general plan for future flights is that each mission will incorporate reflights of two sections with their previous instrumentation and introduce one section with new instrumentation. This reflight philosophy recognizes that experiment refinement is usually appropriate following a first flight and that even completely successful experiments require reproducibility for full credibility.

Typically, the equipment is mounted within the cylindrical section on individual plates that are attached to either side of a pair of longerons that run the length of the section between bulkheads. Thus, an individual experiment can be assembled and tested on its own mounting plate. This is illustrated in Figure 2. The cylindrical exterior skin slides over the assembled section.

An individual section can either be vented to space during flight or it can be sealed to maintain atmospheric pressure. The skins of some sections have doors for access to the equipment late in the launch sequence. This provides access to the experiments within four hours before launch.

Integration and testing of the experiment payload is a Consortium function that is accomplished in Huntsville by a joint UAH and McDonnell Douglas team. Individual experiments are delivered for this process about four to five months before flight. For efficient payload integration, each experiment should have as much electrical autonomy as is practical. A central computer controlled the apparatus on Consort 1, but Consort 2 had more distributed control. Battery power was partially distributed on Consort 1 and Consort 2. Telemetry is available through a central system.

Two accelerometer systems measure the acceleration environment during the free flight, when the experiments occur. Some acceleration data are transmitted to ground by radio and other data are processed and recorded on board the payload. The Starfire launch vehicle provides some 6-8 minutes of free flight with acceleration levels at or below  $10^{-6}$  g's, unless the experiments themselves introduce further accelerations.

### Consort 1

The Consort 1 mission occurred on March 29, 1989. All rocket and payload systems performed as expected. The payload was recovered undamaged. Just over seven minutes of microgravity was achieved. The experiment payload had a mass of about 279 kg. Its three sections had lengths: top 1.52 m, middle 1.30 m, bottom 0.83 m. The middle and bottom sections were sealed. The payload contained instrumentation for six classes of experiments.<sup>4</sup> These are listed in Table 1. Several experiments contained a number of specimens.

Table 1: Consort 1 Investigations

<u>Experiment</u>	<u>Organizations</u>
1. Powdered Metal Sintering	Teledyne Brown Engineering and UAH
2. Materials Dispersion Apparatus	Instrumentation Technology Associates
3. ELectrodeposition and Codeposition	McDonnell Douglas Space Systems and UAH
4. Polymer Demixing	UAH
5. Polymer Foam Formation	Hercules and UAH
6. Elastomer Modified Epoxy Resin	Phillips Petroleum and UAH
7. Controller and Accelerometers	UAH and MSFC

Acceleration measurements from the Consort flight showed that operation of the experiments themselves generated appreciable accelerations. This was expected from mixing motors for experiments 3, 4, and 5 that ran only during the first several seconds of free flight. However, motorized 35 mm cameras of standard commercial design generated acceleration spikes up to 0.1 g when exposures were made and the film was advanced. Acceleration measurements averaged over one second showed that the long-period acceleration environment attained the  $10^{-6}$  goal.

### Consort 2

The Consort 2 payload launched November 15, 1989 was derived from Consort 1 by preparing a new top section and reifying the middle and bottom sections. The furnace for

powdered metal sintering was replaced by biotechnology experiments from the CCDS at Pennsylvania State University and the CCDS at the University of Colorado. The new section also incorporated materials experiments from the CCDS at the Battelle, Columbus Division, Ohio and from Thiokol in Utah, a member of the UAH consortium. See Table 2. The metal sintering section is scheduled for reflight on Consort 4 in 1991.

Table 2: Consort 2 Investigations  
Upper Section

<u>Experiment</u>	<u>Organizations</u>
1. Power Distribution and Control Unit	McDonnell Douglas Space Systems
2. Materials Dispersion Apparatus	Instrumentation Technology Associates
3. Automated Generic Bioprocessing Apparatus	University of Colorado, Kansas State University and Bioserve Space Technologies
4. Biomodule	Penn State University CCDS Center for Cell Research
5. Polymer Thin Film	Thiokol Corporation and USAF Astronautics Lab
6. Polymer Membrane Processing, Multiphase Polymer Curing, and Plasma Polymerization	Battelle Columbus Laboratories CCDS Center for Advanced Materials

Note: Middle and bottom sections were essentially the same as Consort 1 but with several experiment upgrades.

Consort 2 experienced a failure of its roll rate gyroscope at four seconds into the flight. As a consequence, the payload did not reach a low gravity condition for successful acquisition of experiment data. However, the payload was recovered intact with no damage. It will be reflown in May 1990 as Consort 3.

#### Joust Program

##### Prospector Rocket

The Prospector rocket has been selected to launch the Joust experiment payloads. The Space Data Corporation of Chandler, Arizona provides the complete launch and recovery services for this vehicle. Prospector is a single stage vehicle, using the Castor IVA solid propellant motor manufactured by Thiokol. It is a fully guided vehicle with an inertial navigation system and a guidance and control computer. The rocket has jet vanes and movable air vanes for thrust vector control. The diameter of the rocket is 1.016 m. Spin stabilization is not used.

For comparable payload masses, the Prospector offers almost twice as much microgravity time as Starfire I. Figure 3 shows the performance of Prospector. For a nominal 225 kg experiment payload, the maximum altitude is 815 km. Reentry from such a altitude requires use of an ablative heat shield.

Launch operations for Joust missions are conducted at Eastern Test Range, Florida. After parachute deployment, the payload descends to the ocean, about 50 km down range, where it is recovered. During launch, the maximum acceleration experienced is about 18 g's. During return, the acceleration has a brief peak at about 40 g's.

### Joust Experiment Payloads

The experiment payload for Joust missions will be assembled as a single cylindrical section 1.016 m in diameter and about one meter in length. The equivalent of three Consort payload sections can cluster side-by-side in the Joust geometry. Thus, one Joust configuration option can accommodate the same experiment mounting plate dimensions adopted for Consort. As shown in Figure 4, three pairs of longerons at 120° intervals allow the same plates and equipment developed for Consort to be flown on Joust. This configuration will be used on Joust 1, because several experiments flown initially on Consort could benefit from the longer experiment time on Joust. Equipment developed specifically for flight on Joust could, of course, be designed to use the full available dimensions if required. Joust could also carry two payloads designed for STS Get Away Special canisters. The cylindrical exterior of the Joust experiment payload will have doors for late access during launch preparations. This is particularly useful for biotechnology investigations with living or sensitive organic specimens.

### Joust 1

The Joust 1 mission is scheduled for November 1990. The experiments to be flown are given in Table 3. Some of these are derived from Consort experiments to simplify the first Joust payload integration and to give the experimenters a longer low gravity period. An accelerometer system similar to that used on Consort is planned for Joust. A decentralized control philosophy and a centralized power distribution system are planned. Telemetry is available through a central system.

Integration and testing of the Joust experiment payloads is again planned as a Consortium function to be accomplished in Huntsville. This will be done by a joint UAH and Teledyne Brown Engineering Team.

## Evolution of Programs

Suborbital facilities such as Consort and Joust make two distinct contributions to the evolution of commercial space activities: 1) they can complete materials and biotechnology investigations that require only several minutes of free flight or 2) they can develop technology and demonstrate instrumentation for later orbital missions. In both cases, a quick and economical cycle from experiment concept to execution and through refinement is vitally important, if the effort is to have commercial or scientific viability.

There are several classes of investigations that require only several minutes of microgravity environment and several classes that require much longer times. The former includes many processes in which chemical forces are dominant after gravity is removed. It also includes cases in which the desired effect is the elimination of gravity driven sedimentation. On the other hand, crystal growth is typically a process requiring hours or days. Processes that depend on diffusion or very slow fluid flow likewise require hours or days. For those processes that require only

minutes, a suborbital rocket is a more effective mode of investigation than an orbital vehicle. This is particularly true if the orbital vehicle is manned and equipment must satisfy rigorous safety standards.

Table 3: Joust 1 Investigations

Experiments	Organizations
1. Electrodeposition and Codeposition	McDonnell Douglas Space Systems and UAH
2. Foam	Fiberglass Canada and UAH
3. Metallurgy	American Kennametal and UAH
4. Thin Films	Thiokol Corporation
5. Automated Generic Bioprocessing Apparatus	University of Colorado, Kansas State University, Bioserve Space Technologies
6. Biomodule	Penn State University CCDS Center for Cell Research
7. Polymer Membrane Processing, Multiphase Polymer Curing, and Plasma Polymerization	Battelle Columbus Laboratories CCDS Center for Advanced Materials
8. Power Distribution and Control Unit	Auburn University CCDS Space Power Institute
9. Accelerometer	UAH

A small unmanned orbital vehicle with automated reentry and recovery has many common features with a Consort or Joust mission. Hence, experience with such operations can be directly applicable to orbital options. This is an example of the second kind of contribution that a suborbital rocket program can make to the evolution of space activities.

Some of the instrumentation developed for suborbital use can be applied in other ways in orbital circumstances. For example, some electrodeposition topics can be investigated in several minutes. Others, such as the deposition of thick layers, need longer times. Successful equipment operation for several minutes does much to insure satisfactory operation for longer times in the more expensive orbital environment.

Even the independent experiment mounting plate approach used on Consort and Joust has natural extensions to orbital use. Clearly it can be and has been applied in Get Away Special canisters. Also, the Consortium is defining a common container for use either in Spacehab, in the STS middeck, or in a Spacelab rack. The dimensions of this container are such that Consort and Joust instrumentation on its mounting plate can fit directly into the container. This should help make instrumentation for Shuttle use more economical to obtain.

#### Summary and Conclusions

The six to eight minute Consort flights and the 13-15 minute Joust flights allow a choice of low gravity short duration missions. These provide flight opportunities not only for the NASA Centers for the Commercial Development in Space, but also for other domestic and foreign

experimenters. Both rockets are built with proven solid rocket boosters, lending a high probability of success to a given mission.

The use of suborbital flights not only allows up to 15 minutes of low gravity, but also provides a reasonably inexpensive carrier to prove the operation of experimental apparatus in low gravity, before the apparatus is flown on a longer duration mission. Careful planning of the design of the apparatus permits using the same or similar apparatus not only on sounding rockets but also on orbiting vehicles such as the United States Space Transportation System or an orbiting free flying platform such as AMICA.

The successful launch of Consort 1 demonstrated the efficiency of cooperation between a university, an aerospace company and a commercial rocket supplier. The first Joust launch is scheduled for November 1990. The purposes are to accomplish materials and biotechnology investigations having commercial value and to stimulate the commercial rocket industry in the United States.

These launches are pathfinders in defining and accomplishing the proper procedures to follow in order to have successful commercial launches from two launch ranges in the United States. The relevant governmental organizations display an attitude of helpfulness and cooperation in working with the launch team fulfilling the necessary regulations. The launch ranges also display this positive attitude.

From the discussions above, important continuing goals for suborbital missions such as Consort and Joust seem assured. The Consort 1 and Consort 2 launches and firm plans for subsequent missions make attainment of these goals a realistic prospect.

#### Acknowledgement

The work described here is supported in part by the National Aeronautics and Space Administration Office of Commercial Programs through grant #NAGW-812.

#### References

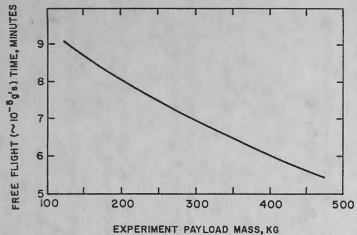
<sup>1</sup>NASA Technical Memorandum, NASA TM-78217, January 1979, "Description of Space Processing Applications Rocket (SPAR) Experiment," Edited by R. J. Naumann.

<sup>2</sup>Charles A. Lundquist and Francis C. Wessling, "Microgravity Investigations on Suborbital Rockets," presented at the IAF 40th International Astronautical Congress, October 7-13, 1989; Malaga, Spain. IAF #89-425.

<sup>3</sup>Francis C. Wessling and George W. Maybee, "Consort 1 Sounding Rocket Flight," Journal of Spacecraft and Rockets, Vol. 25, No. 5, September-October 1989, pp. 343-351.

<sup>4</sup>Francis C. Wessling, Charles A. Lundquist and George W. Maybee, "Consort 1 Flight Results - A Synopsis," presented at the IAF 40th International Astronautical Congress, October 7-13, 1989; Malaga, Spain. IAF #89-439. To be published in Acta Astronautica in 1990.

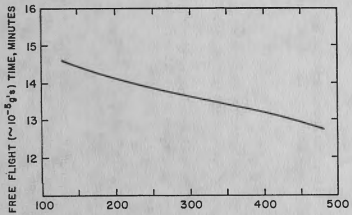




EXPERIMENT PAYLOAD MASS, KG

FIGURE 1

STARFIRE I PERFORMANCE



EXPERIMENT PAYLOAD MASS, KG

FIGURE 3

PROSPECTOR PERFORMANCE

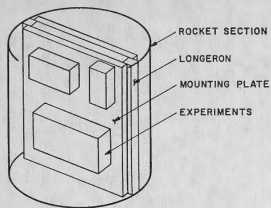


FIGURE 2

CONSORT PAYLOAD SECTION

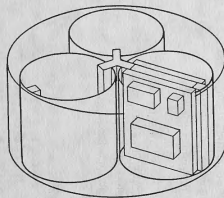


FIGURE 4

JOUST PAYLOAD SECTION