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Paper Session I-C - Autonomous Microgravity Industrial Carrier (AMICA) Initiative

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THE AUTONOMOUS MICROGRAVITY

INDUSTRIAL CARRIER (AMICA) INITIATIVE

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INTRODUCTION

GE Astro-Space Division, Princeton, New Jersey, has joined with MBB-ERNO of Germany, Aeritalia, and MATRA, in proposing a program employing two spacecraft which would offer flight opportunities to the space science community in the 1990s. The first of these spacecraft would be obtained by transfer of the European Retrievable Carrier (EURECA) to this initiative. EURECA is a spacecraft currently under development, scheduled for launch in May 1991 and retrieval in January 1992. The second spacecraft, called the Autonomous Microgravity Industrial Carrier (AMICA), would also be built, as a duplicate of EURECA. The entire program is referred to as the AMICA Initiative.

AMICA is a free-flyer spacecraft that features the highest degree of microgravity, extended flight duration, cleanliness, retrievability and re-flight. It is therefore a key element in the 1990s industrialization of space.

The program evolves from the EURECA program which will in 1991 carry a variety of experiments in Solar Physics, Atmospheric Physics, Gamma-Ray Astronomy, Astrophysics, Materials Science, Life Science, and technology development. The EURECA spacecraft, in turn, employs techniques used in the Shuttle Pallet Satellite. AMICA, therefore, represents a low-risk approach based on extensive space flight experience.

This paper provides an overview of the EURECA/AMICA program approach. Characteristics of the spacecraft and the spacecraft/payload interfaces are described. The applicability of AMICA to a wide variety of science and applied technology experiments, as demonstrated by the EURECA-1 payload complement, is discussed.
The AMICA program approach employs two spacecraft. The schedule of application of these two spacecraft is shown in Figure 1, which also demonstrates the value of such a capability. The flight of the current EURECA-1 program ends with retrieval in January 1991. At that point, the EURECA spacecraft is transferred to the AMICA Initiative to become one of the two AMICA program spacecraft. Meanwhile, a duplicate of the EURECA spacecraft (AMICA) will have been in production, and in preparation for launch in late 1992. Thereafter, a launch on approximately a yearly basis is the goal. The duration of each mission is nominally six months.

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Figure 1. Microgravity Research Flight Opportunities

Figure 1 also illustrates the schedule of flight opportunities for retrievable experiments in the absence of a program such as AMICA. Capability is limited to that provided by shuttle sortie missions. This figure shows the manifested primary missions of microgravity research. These missions are limited to 14 days or less, attached to the shuttle bay and subjected to the shuttle environment. Also shown is the flight of the Japanese free-flyer, the Space Flyer Unit.

W13/11-976/MR
scheduled for flight in 1993. The SFU mission will demonstrate equipment destined for the Japanese Experiment Module on the Space Station Freedom, and some microgravity research experiments will be conducted. As Figure 1 illustrates, the AMICA program provides a capability valuable to those who need longer duration flight with retrieval of experiment equipment in the period preceding availability of the Space Station.

The program evolves from the European development of retrievable free-flyers for experiment missions. The first of these was the Shuttle Pallet Satellite (SPAS) which was flown in shuttle sortie missions in the 1980's. In these missions, a platform carrying a variety of experiments was deployed from the shuttle. Experiments were conducted while the platform flew in a co-orbit with the shuttle. At the end of each shuttle mission, the platform was retrieved and returned to earth.

Some of the techniques and technology of SPAS, such as the basic structure, have been incorporated in the EURECA-1 spacecraft which is well on its way to launch via the shuttle in May 1991. Figure 2 is a photograph of the EURECA-1 flight spacecraft, where final integration and checkout of payload has commenced.
Because of the SPAS and EURECA-1 heritage, AMICA is viewed as a low-risk development.

THE EURECA-1 MISSION OBJECTIVES

EURECA provides the user community with a unique research environment in terms of on-orbit stay time (i.e., 6 months) and its high quality microgravity environment (better than $10^{-6}$ g below 1 Hz).

As a main design feature EURECA offers great flexibility for accommodating science requirements as well as for satisfying the needs of advanced technology development programs.

EURECA Mission 1 is primarily dedicated to microgravity research projects. The related "micro-g multi-user facilities" make up about 70% of the total available payload mass of 1000 Kg.

In addition to this, Mission 1 serves the needs of multiple disciplines, i.e., it accommodates experiments from the fields of solar physics, atmospheric physics, γ-ray astronomy, astrophysics, and serves various investigations regarding development of advanced technologies.

In the following, these instruments and their experimental objectives are briefly described.

**Automatic Monoellipsoid Mirror Furnace Facility (AMF)**

The AMF is an optical radiation furnace, particularly suited for crystal growth experiments. It is derived from a similar SPACELAB (D1) development. The facility is characterized by the sequential processing of 23 samples. Sample exchange, rotation and translation within the furnace are effected by an automated revolver mechanism. The investigations are:

- High temperature solution growth of Gd-Mg compound
- Growth of single crystals of $\text{Bi}_{12}\text{SiO}_{20}$
- Growth of II-VI semiconductors from vapor
- THM solution growth of II-VI semiconductors
- Solution growth of ternary sulphides by the THM
- THM solution growth of III-V semiconductors
- Solution growth of $\text{Pb}_1-x\text{Sn}_x\text{Te}$ by the THM
Multi-Furnace-Assembly (MFA)

The MFA (Figure 3) provides a number of furnaces with a common mechanical, thermal, and electrical infrastructure. During the first mission 12 furnaces of three different types will accommodate five experiments which deal with the wetting characteristics of different ceramic materials by liquid monotectic alloys, measurement of thermal diffusion in binary alloys, obtaining nearly perfect lead-tin telluride monocrystals, demonstrating the liquid-phase sintering of metals and studying the Ostwald-ripening phenomenon in Al-In and Zn-Pb monotectic alloys.

![Multi Furnace Assembly](image)

Figure 3. Multi Furnace Assembly

Protein Crystallization Facility (PCF)

The PCF design (Figure 4) employs 12 reactor vessels which provide an individually controlled temperature environment for each of the 12 samples. Each vessel consists of three adjacent chambers, carrying a protein, a salt solution and a buffer solution, respectively. Protein crystallization is initiated by allowing the protein and salt-chamber solutions to diffuse into the reaction chamber. Proteins under investigation are Lysozyme, β-galactosidase, rhodopsin, β-crustacyanin, plasminogen, and fibrinogen.

Exobiological Radiation Assembly (ERA)

The ERA is an interdisciplinary facility, covering microbiology, biochemistry and biophysics. The following phenomena are studied: the formation, stability and destruction of organic molecules and polymers, the biological
response of membranes, bacterial spores, staphylococcus aureus, yeast, sordaria spores to the microgravity environment, the aging of complex organisms, the effects of HZE particle and deep UV on living systems. ERA is divided into the following elements: a deployable tray for samples that require partial (timelined) solar exposure; a vented tray for samples that require hard vacuum exposure and a compartment accommodating six Bistack units.

**Solution Growth Facility (SGF)**

The SGF reactors allow two reactant solutions to diffuse slowly into a buffer chamber filled with pure solvent, in which they react and nucleate to form single-crystals of the desired substance. One experiment is devoted to the growth of organic components which feature special properties as an isotropic electrical conductors.

Calcium carbonate, which is grown in the second experiment reactor, has useful optical properties and is of interest in the basic research on crystal growth in bio-environments.

The third experiment is devoted to the crystallization of zeolite crystals, big enough to enable the diffractiometric identification of their basic structure.

The fourth reactor is subdivided into twenty individual sample tubes for the measurement of the Soret-coefficients of binary mixtures.
High Precision Thermostat (HPT)

The high precision thermostat measures physical parameters of a test fluid. The behavior of the test fluid SF, very near the critical point of the pressure/temperature relationship is of specific interest.

Surface Forces Adhesion Experiment (SFA)

The SFA is employed to shed light on the mechanisms of adhesion between solid bodies having real surfaces, contributing to the understanding of adhesion related phenomena, such as friction and wear. The possibility of using cold welding techniques in microgravity will be investigated.

From the space science disciplines the following experiments will be performed on-board EURECA-1.

Solar Spectrum Experiment (SOSP)

The Solar Spectrum Experiment, which measures the solar irradiances from 170 to 3200 mm, and their variabilities. The measurements are related to solar-terrestrial/planet relationship (in particular mesospheric, stratospheric and tropospheric aeronomy).

Solar Variation Experiment (SOVA)

SOVA measures solar irradiance absolute values and variations, solar irradiance oscillations, and solar spectral irradiance variations.

Occulation Radiometer (ORA)

ORA determines abundance profiles of water vapor and carbon dioxide in the terrestrial mesosphere, and studies the middle atmospheric aerosol extinction and the abundance profiles of ozone, nitrogen dioxide and water vapor.

Wide Angle Telescope for Cosmic and Hard X-Ray Transients (WATCH)

WATCH is designed for rapid localization of hard x-ray transient sources, in particular the so-called cosmic gamma bursts.

Timeband Capture Cell Experiments (TICCE)

The objectives of TICCE are to study the microparticle population in near-Earth space, by retrieving samples of it and noting the impact rate, the epoch of the capture and the incident direction.

Finally three experiment packages for advanced technology development are carried on the EURECA's first mission.

Radio frequency Ionization Thruster Assembly (RITA)

RITA is an ion propulsion unit at a thrust level of 5 to 10 mN. The objective of this experiment is to operate the RITA system in a real space environment and to compare space and ground test performance data and to obtain operational experience of the RITA system.

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Inter-Orbit Communication (IOC)

The IOC experiment has the objective of providing an in-flight test and demonstration of the main functions, services, and equipment to be operated by a data relay satellite system (DRS), i.e., tracking of the user spacecraft to a dedicated ground terminal, and TTC services to the user spacecraft.

Advanced Solar Gallium Arsenide Array (ASGA)

ASGA consists of a solar panel of advanced GaAs solar cells to test their behavior in space environment. It also comprises a calibration experiment and a small light concentrator.

AMICA SYSTEM OVERVIEW

For AMICA ground operations, a "ship-and-shoot" concept has been adopted, i.e., instrument integration and checkout take place at the AMICA home base, which - pending on the specific mission - will be in the US or Europe. In this way, the users have direct access to their instruments and experimental hardware during the integration and checkout period. The fully equipped and tested platform is then transported to the shuttle launch site, loaded into the Orbiter cargo bay and readied for launch.

Mission Scenario (Figure 5)
The AMICA platform is launched by the US Space Shuttle together with other shuttle payloads in a shared mission. It is put into a 300 km/28.5° orbit by the shuttle remote manipulator arm.

During the climb phase of the Orbiter, the platform is supplied with power from the transport system, since additional energy has to be made available for thermal control. During this phase, the shuttle also acts as a relay station for data transmission since it may take several days before EURECA is set into its orbit. When on orbit, the platform is deployed by the Shuttle manipulator arm, solar arrays are extended, and operating systems are activated.

When telemetry and power supply are switched on, the command for orientation and positioning is given.

AMICA's on-board propulsion system then autonomously performs the transfer into the operational orbit, approximately 525 km altitude.
ALTITUDE

625 km

PLATFORM COMMISSIONING AND PREPARATION 3 DAYS
FULLY SUPPORTED PAYLOAD OPERATIONS AND SPACE-TO-GROUND DATA COMMUNICATIONS
SAME AS FOR ON-ORBIT OPERATIONAL PHASE EXCEPT THAT ACTIVE COOLING OFF

PLATFORM ASCENT OTM TO OPERATIONAL ORBIT

AMICA/EURECA DEPLOYMENT AND ACTIVATION FOR ORBIT TRANSFER

OPERATIONAL ORBIT

TRANSFER TO MISSION ORBIT

TRANSFER TO RETRIEVAL ORBIT

DEPLOYMENT

RETRIEVAL

SHUTTLE CARGO BAY PARKING

DEOBLIT

SHUTTLE II

DEOBLIT

SHUTTLE CARGO BAY PARKING

SHUTTLE DEACTIVATION

SHUTTLE DESCENT AND LANDING

PRE-OPERATIONAL PHASE 7 DAYS
ON-ORBIT OPERATIONAL PHASE 180 DAYS
POST-OPERATIONAL PHASE
ON-ORBIT DORMANT 90 DAYS
RETRIEVAL 9 DAYS

Figure 5. AMICA Mission Scenario
The spacecraft orbit altitude is allowed to decay over the six-month mission. Re-boost is avoided so that the quiescent microgravity environment is not perturbed. At the end of the mission a transfer to 300 Km occurs to rendezvous with the STS for retrieval and return to earth.

After each mission, AMICA is returned to its home base for preparation of the next mission with exchange of payloads and all necessary refurbishment of the platform.

Operational Data Distribution (Figure 6)
The concept for the mission operations of the AMICA Platform and payload embodies the following characteristics.

- A Mission Operations Control Center for AMICA (MOCCA) will be set up in the existing General Electric Astro Satellite Operation Center (ASOC) in New Jersey, USA.
  This center is linked to the two General Electric Ground Stations, one on Guam and the other in Carpentersville, New Jersey.

- An international Payload Support Center will be set up at MBB/ERNO, Bremen, West Germany, to process and distribute the international payload data to the payload home bases, to provide the necessary mission support to the international payload specialists (except USA) as well as home-base engineering support to ASOC for the platform operations.

- The MOCCA will include a similar Payload Support Center for the US payloads which will be responsible for distributing the daily payload data to the US users.

- The daily transmissions of the payload data from the MOCCA to the international Payload Support Center (and the payload Master Schedule requirements in the opposite direction) will be done using commercial transatlantic communications.

**SPACECRAFT FEATURES**

Figure 7 summarizes features of the spacecraft. Of the total spacecraft of 4400 Kg, one thousand kilograms is collocated to payloads.

Figure 8 illustrates the spacecraft in a folded solar array configuration. Payload are mounted on the platform as shown. The available volume topside is 8.5 m$^3$ and it is possible to mount payloads elsewhere. For example, the Inter Orbit Communications package is mounted on the bottom structure on the EURECA-1 spacecraft.
Figure 6. Data Transmission to User's Locations During Missions

<table>
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<tr>
<td>Volume</td>
<td>Available to Payload</td>
<td>1000 kg</td>
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<tr>
<td>Power</td>
<td>Available to Payload</td>
<td>8.5 Cubic Meters</td>
</tr>
<tr>
<td>Thermal Control</td>
<td>Available to Payload</td>
<td>1000 W</td>
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<tr>
<td>Data Management</td>
<td>Peak</td>
<td>1500 W</td>
</tr>
<tr>
<td>Attitude Pointing Accuracy</td>
<td>Solar Array Output</td>
<td>5000 W</td>
</tr>
<tr>
<td>Microgravity (Achievable)</td>
<td>Liquid Freon Loop (1000 W) and Multi Layer Insulation</td>
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<tr>
<td>Orbit</td>
<td>High Speed</td>
<td>256 kbps</td>
</tr>
<tr>
<td>Mission Duration</td>
<td>Low Speed</td>
<td>2 kbps</td>
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<tr>
<td>Design Life</td>
<td>Memory Capacity</td>
<td>126 Mbits</td>
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<tr>
<td></td>
<td>Average P/L</td>
<td>1.5 kbps</td>
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<td>1 Degree (3 Sigma) g &lt; 0.1 Hz: 8 \cdot 10^{-7}</td>
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<td>g &gt; 100 Hz: 10^{-3}</td>
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Figure 7. Spacecraft Features

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Total spacecraft power of 5000 watts is derived from solar array and batteries. Of this, 1000 watts is available continuously to the total payload complement. Peak power of 1500 watts is available for 15 minutes periodically.

Passive and active cooling of the spacecraft is provided. Active cooling is via a liquid Freon loop, capable of removing 1000 thermal watts.

Data links, as described in the system overview above, include both high and low speed links, with an on-orbit data storage capacity of 126 megabits.

The microgravity spectrum has been determined by test. These tests show that the magnitude of worst-case perturbations, in the frequency range less than 0.1 Hz, will be less than $10^{-6}$g. Worst-case perturbations in the frequency range greater than 100 Hz will be of magnitudes less than $10^{-3}$g. There is a linear increase of worst-case disturbances between 0.1 Hz and 100 Hz. This environment is achieved by design specifically oriented to achieving the lowest possible gravity disturbances. The platform is configured to locate payloads close to the spacecraft center-of-mass, and fuel storage and usage is designed to maintain the center-of-mass position for six months. Spacecraft center body cross section has

Figure 8. AMICA Payload Accommodation Envelope
been minimized to less than 8 m² to minimize drag. Solar array power versus
drag cross section has been optimized, and the spacecraft flies in the direction
of solar array extension.

Orbit altitude selection considers the effects of solar activity on expansion of
the atmosphere. At an altitude of 525 Km, six months low drag flight is expected
under worst-case sun spot activity. Mission duration, of course, can extend for
longer duration–resources provide for orbit life up to 2 years -- but the stated
levels of microgravity cannot be guaranteed beyond six months.

A key objective of design and spacecraft operation is to keep the platform as
quiet as possible. Orbit is allowed to decay without re-boost. For attitude
control, magnetic torquers and minute 20 mN thrusters are used. While on orbit,
cold gas (nitrogen) only is used, to minimize contamination. Use of
electro-mechanical devices is avoided. Solar arrays are fixed; the spacecraft is
inertially oriented toward the sun. Bubble memory is employed instead of tape
recorders. Uplink and downlink communications are via fixed antennas.

PAYLOAD ACCOMMODATIONS

A total of 1000 Kg of payload equipment can be accommodated. This equipment is
generally mounted topside as shown previously in Figure 8, with the possibility of
accommodating limited packages elsewhere.

Key interface features, in the areas of structure, thermal control, power and
data, are described next.

Structural Interface

As shown in Figure 9, the spacecraft structure is comprised of an array of 12
Equipment Support Panels fastened atop a modular truss. The truss is
constructed from carbon fiber reinforced struts and titanium nodes. Each
panel is approximately two feet by two feet, and larger instruments can be
mounted on multiple panels. Equipment which requires active cooling can be
mounted on a cold plate, which in turn is mounted on the equipment support
panel. Equipment can also be mounted directly to nodes of the modular truss
structure.

Thermal Interface

Figure 10 illustrates alternative payload cooling techniques. Active thermal
control is performed by tapping into the spacecraft active Freon-114 cooling
loop. Coolant can flow through a cold plate upon which the equipment is
mounted, or equipment can access and utilize the cooling loop directly, which
provides a total payload heat rejection of 1 kw. The nominal coolant mass
flow rate is 1200 Kg/hour at a maximum operating pressure of 1.37 mpa.
Allowable pressure drop across instrument or cold plate is 200 kpa. This cooling loop operates only during the on-orbit operational phase.

Passive thermal control may be realized by multi-layer insulation, and actively by heaters. During normal operations, 100 W is available; otherwise 200 W is available during pre-deployment, dormant and post-retrieval phases, and 120 W during deployment and retrieval, shared with spacecraft subsystems.

Power and Data Interfaces

Power. Figure 11 describes the power and data interfaces. Primary power, derived from the extended solar arrays, is provided to instruments via the Power Distribution Unit (PDU). Steady state voltage is 28 V at 14 outlets which provide current in the range from 8 to 35 amps.

Instrument heater power is provided from the TCU, at 15 W or 55 W outlets. Total heater power is 200 W, and is available at all times from opening of the shuttle bay doors to closure after retrieval.
Coldplate
Direct Cooling
Surface Cooling

Figure 10. Payload Cooling

Figure 11. Electrical Payload Interfaces
The total 1000 W is time-shared by instruments throughout the mission. For example, the power usage profile for the EURECA-1 mission is shown in Figure 12. Some instruments, such as the SGF, PCF and ERA, maintain a steady, uninterrupted drain throughout the 180 day mission. Other instruments, such as the AMF, RITA and MFA, use power on an interrupted basis as required for their experiments.

![Figure 12. EURECA Mission 1 Payload Power Timeline](image)

Development of this time-shared profile is an important task in mission planning to efficiently utilize the available 1000 W, while satisfying all equipment needs.

Data. The core of the Data Handling Subsystem are the central processor, the Power Processing Unit (PPU) and its memory, the Mass Memory Unit (MMU).

Payload instruments normally interface with the spacecraft Data Handling Subsystem via the Remote Acquisition Unit (RAU), the Processor Interface Adapter (PIA), or the Monitoring and Reconfiguration Unit (MRU).

The RAU provides:

- **DO**: Discrete low-level outputs (5 V commands) to the P/L, either pulse or bi-level.
- **DI**: Discrete 5 V bi-level input channels, providing P/L status information.

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• AL: Analog input channels encoding positive or symmetric 10 V ranges of payload analog measurements.

• SI and SO: Serial in/out channels for packetized telemetry/telecommand traffic up to 128 kbps burst.

• Clock and Time output channels for distribution of time information with accuracy of 1 ms.

The PIA provides:

• 8 ON/OFF commands; level: 5 V (continuous). The 5 V ON/OFF command is designed to drive directly an optocoupler.

• 8 ON/OFF commands; level: 28 V; 100 msec pulse.

• 16 discrete inputs, 5 V level.

• 1 User time clock channel.

• 1 User time clock update channel.

• 1 PIA-488 Bus for maximum 8 instruments.

The MRU provides optional services for high-level command and contact monitoring independent of PPU status.

Optional command and telemetry interfaces are provided to the main central processor, the Powerful Processing Unit (PPU) and its 128 Mbit bubble memory, the Mass Memory Unit (MMU).

In addition, for ground operations, instrument dedicated data and power lines provide links via the Remotely Operated Electrical Umbilical to ground equipment.

PROGRAM SUPPORT

In addition to the system elements, spacecraft, and operations described above, the AMICA Company will provide support to minimize the burden of program requirements to the payload user. These support activities include:

• Testing of Payload Engineering and Flight Units

• NASA Safety Reviews of Payload Instruments

• System Integration and Test

• Transportation to Launch Site

• Pre-Launch Activities

• Launch and Retrieval of Instrument

• Data Transmission to User's location during Mission

• Post Mission Processing
SUMMARY

The AMICA Initiative offers flight opportunities which satisfy the needs of many experimenters in the 1990's time period leading to the availability of the Space Station. Two spacecraft will provide for frequent flights and retrieval after flights of extended duration. The spacecraft and its operation have been designed to provide the lowest gravity, quiescent environment. Platform design is flexible so that a variety of science and technology users can be accommodated. The mission operation approach offers ease of experiment interaction to users, with prompt availability of experiment data. Use of developed and qualified EURECA technology offers cost advantage and minimized risk to user agencies.