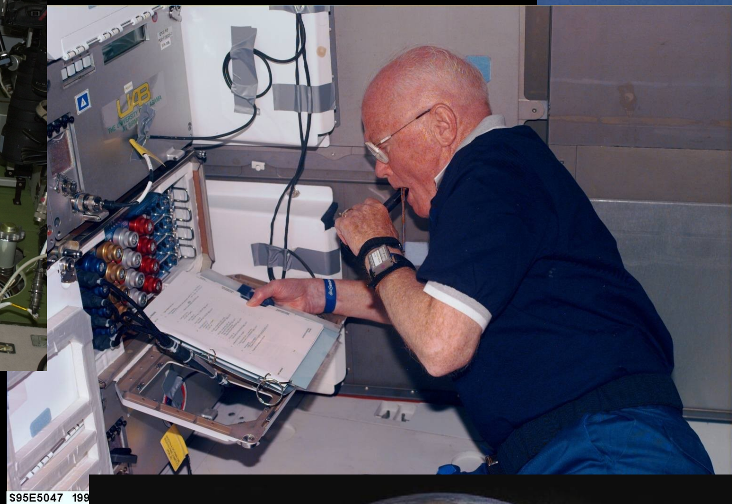
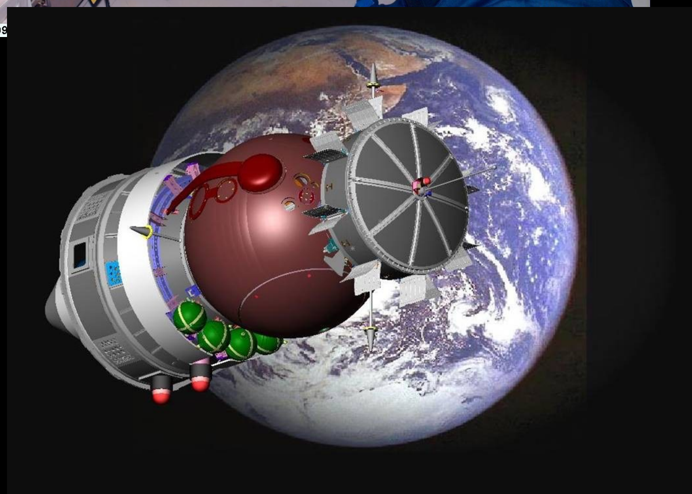
Science in Microgravity

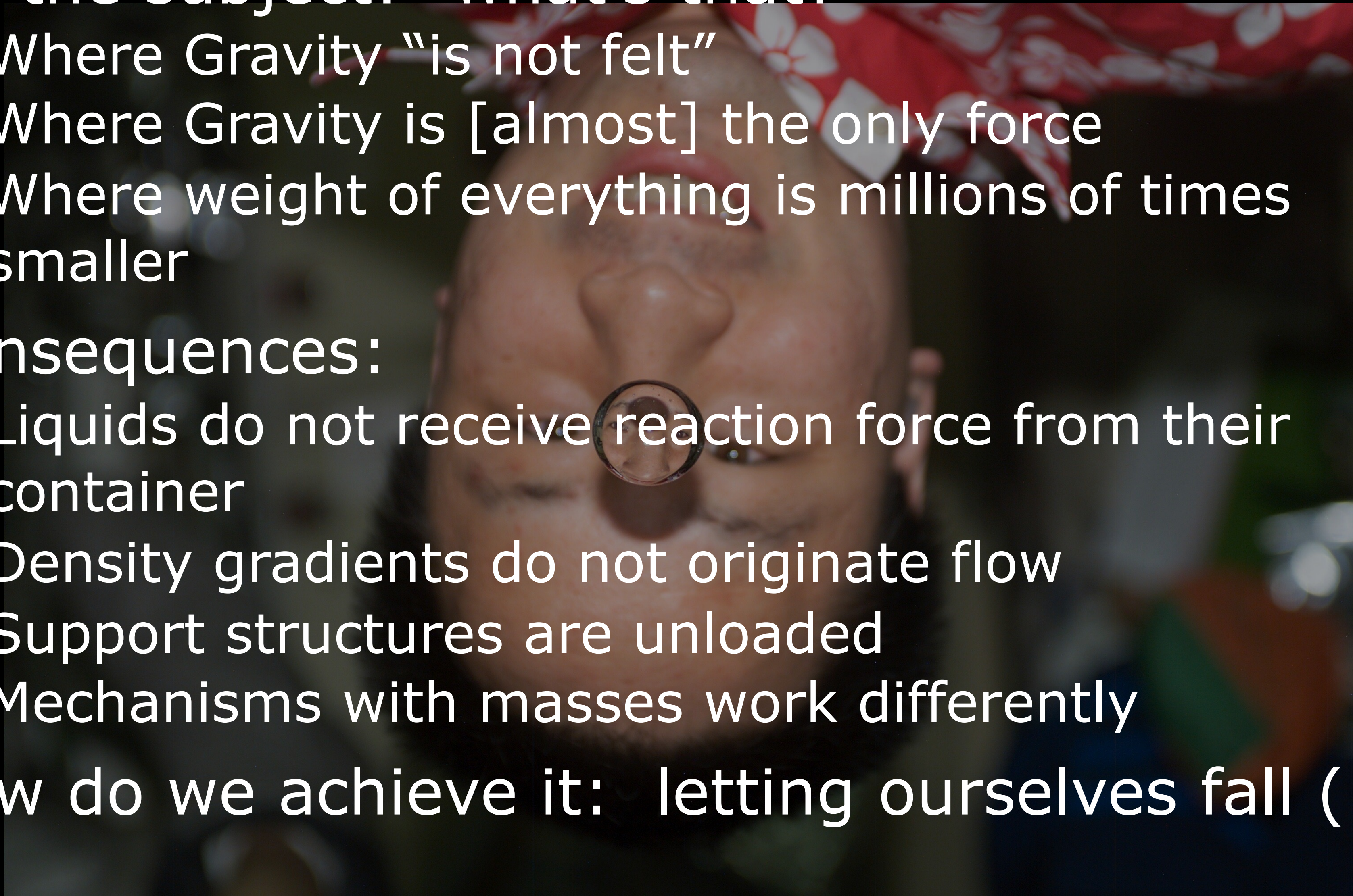
ESAC 15.12.2016

Science in Microgravity





Microgravity (µg)



- On the subject: “what’s that?”
  - Where Gravity “is not felt”
  - Where Gravity is [almost] the only force
  - Where weight of everything is millions of times smaller
- Consequences:
  - Liquids do not receive reaction force from their container
  - Density gradients do not originate flow
  - Support structures are unloaded
  - Mechanisms with masses work differently
- How do we achieve it: letting ourselves fall (!!!)

Why Investigate in µg

- To measure better basic magnitudes
  - For better models in physics
- To obtain in reality theoretical results
  - To compare with industrial results and help improve the processes
- To improve systems or study human reaction
  - With a view towards human exploration, lunar bases, etc.
- To observe in these conditions
  - Expecting new ideas to generate scientific hypotheses

Research Areas in µg

- Fluids – generic
  - Interfases, phase change, convection, critical fluids, colloids, foams, combustion

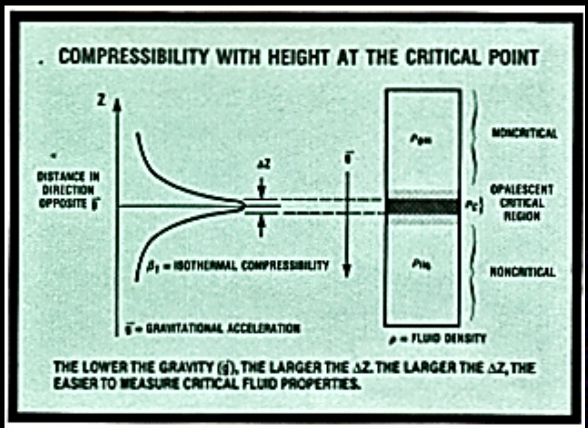
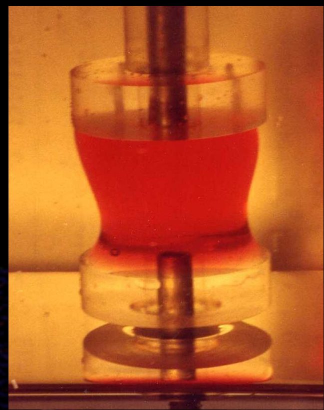
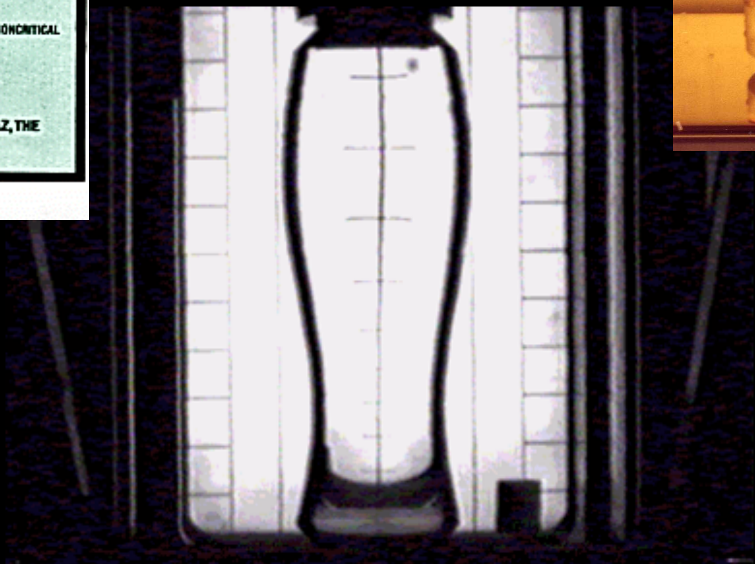
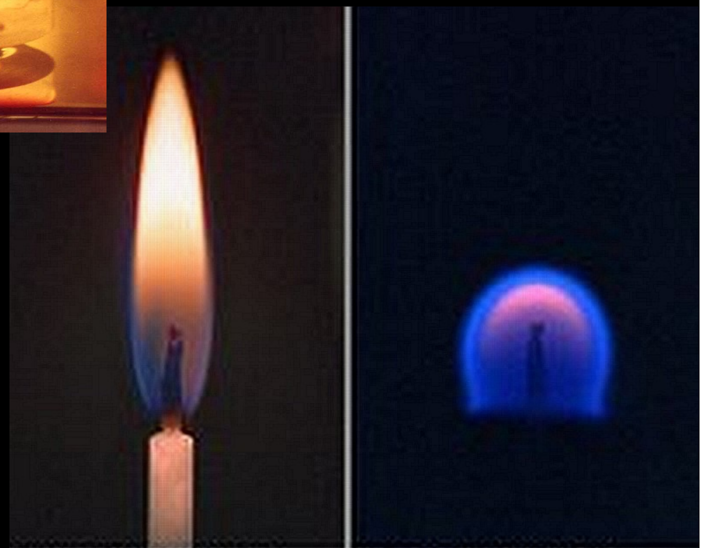


Figure 1.–Fluid compressibility with height near the critical point.

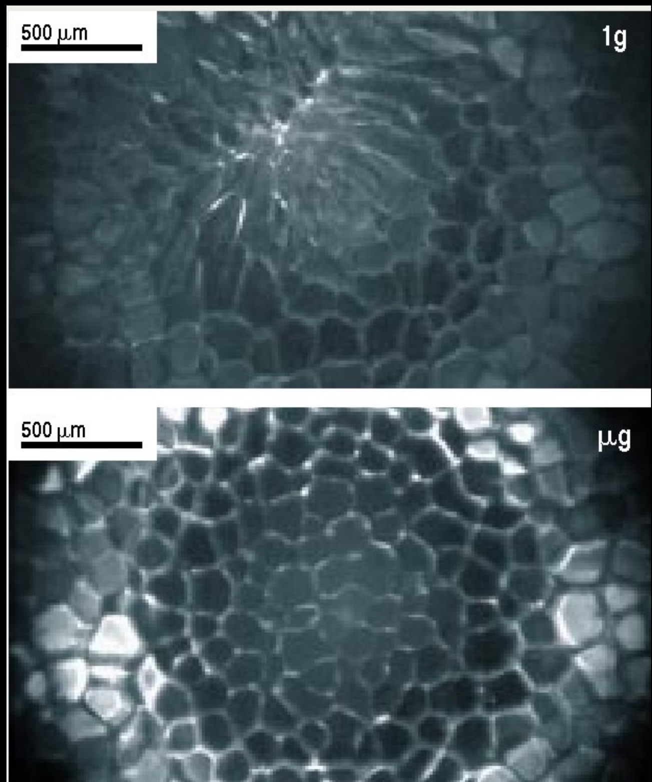


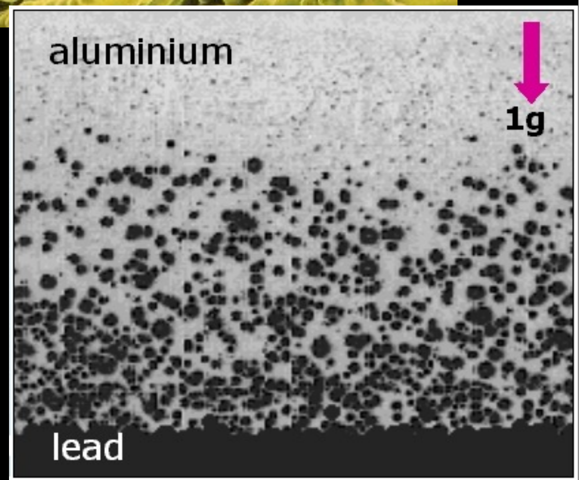




Research Areas in µg

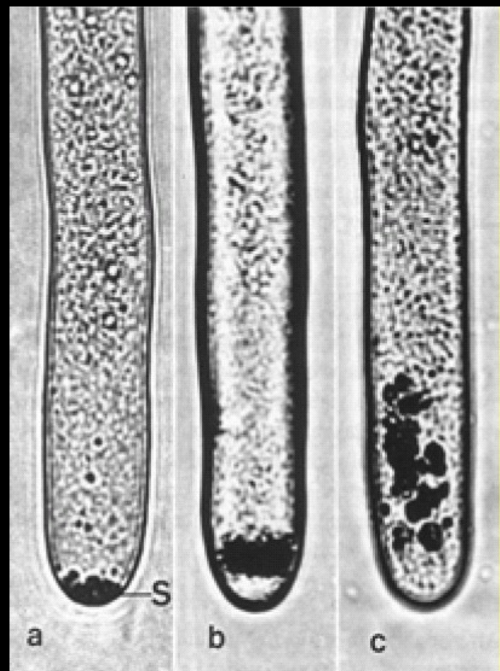
- Materials
  - Complex Alloys, Autolubricants, Exact Properties, Semiconductors

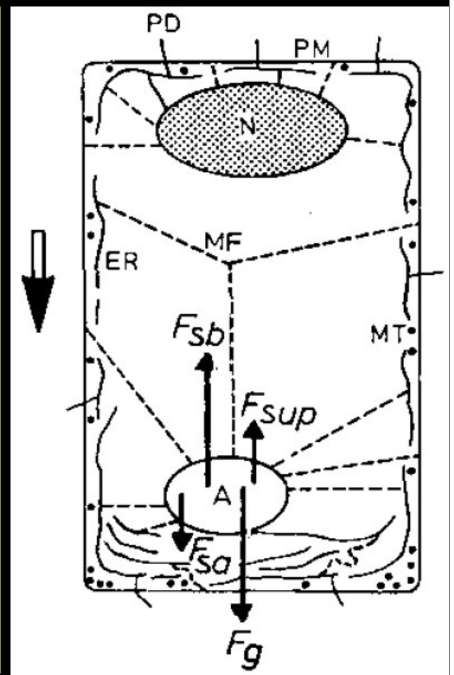




Research Areas in µg

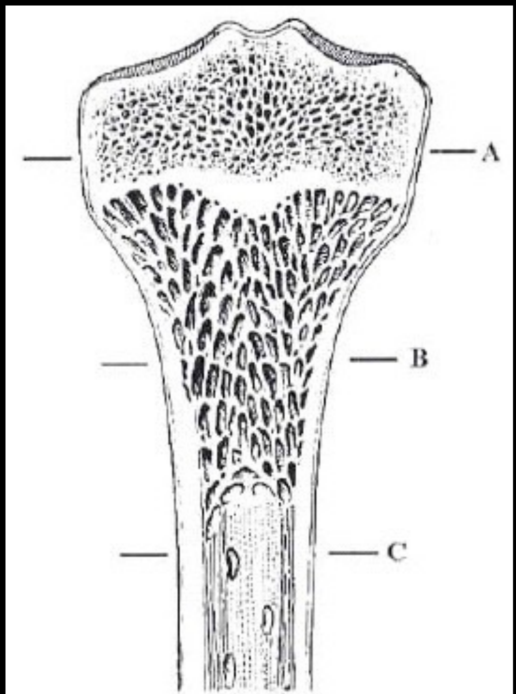
- Biology
  - Plant Growth, Differentiation of Embryos, Gene Expression





Research Areas in µg

- Medicine / Physiology
  - Balance, Lungs, Heart, Rhythms, Bones, Muscles...



How to Achieve μg

Drop Towers

Parabolic Flights

Sounding Rockets

Automatic Satellites

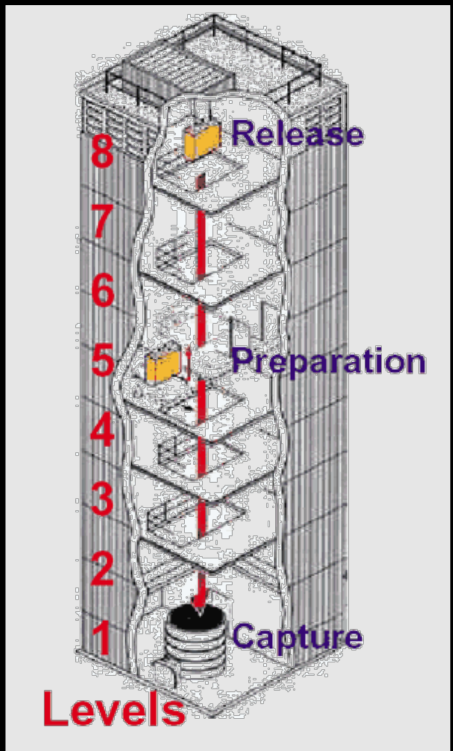
Space Station

How to Achieve µg – Drop Towers

- Invented by W. Watts in Bristol (UK, 1775)
  - Without convection, without container = perfect spheres of lead, best projectiles of their time
- Currently drop towers raise up to 150m (4/8 sec) or down into a shaft (up to 10 sec)
- Experiment Size: 20-40 cm
- Repetitions: 3 / day
- Everything must be automatic

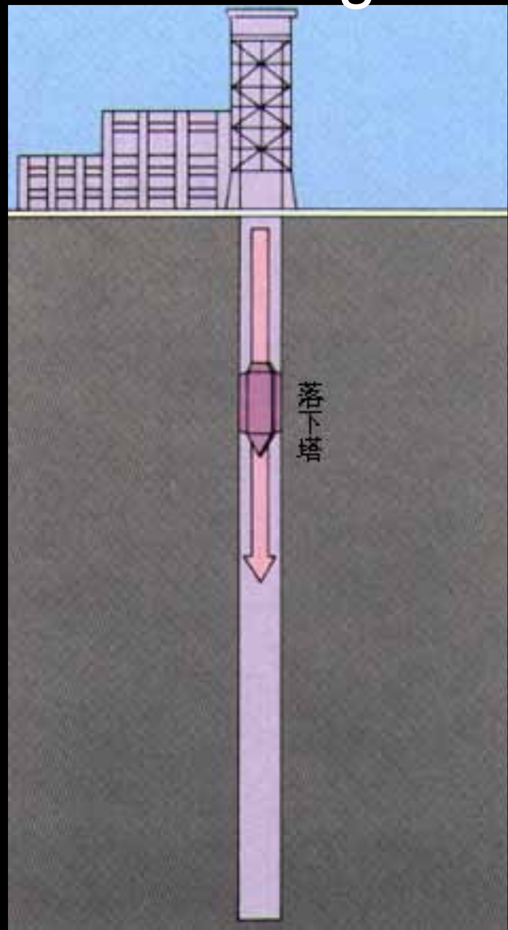
How to Achieve µg – Drop Towers

NASA - Glenn



A cutaway drawing of the 2.2 Second Drop Tower, showing the levels on which an experiment package is prepared, released, and captured.

Kamisunagawa



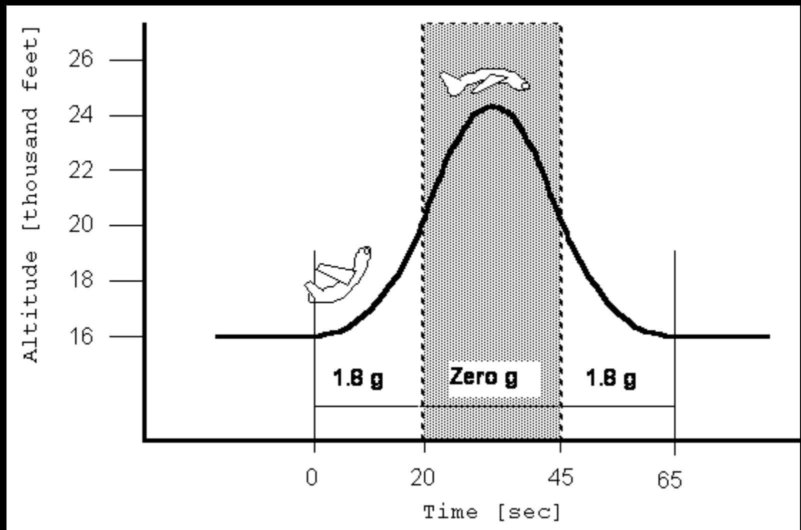
Bremen

How to Achieve µg – Drop Towers

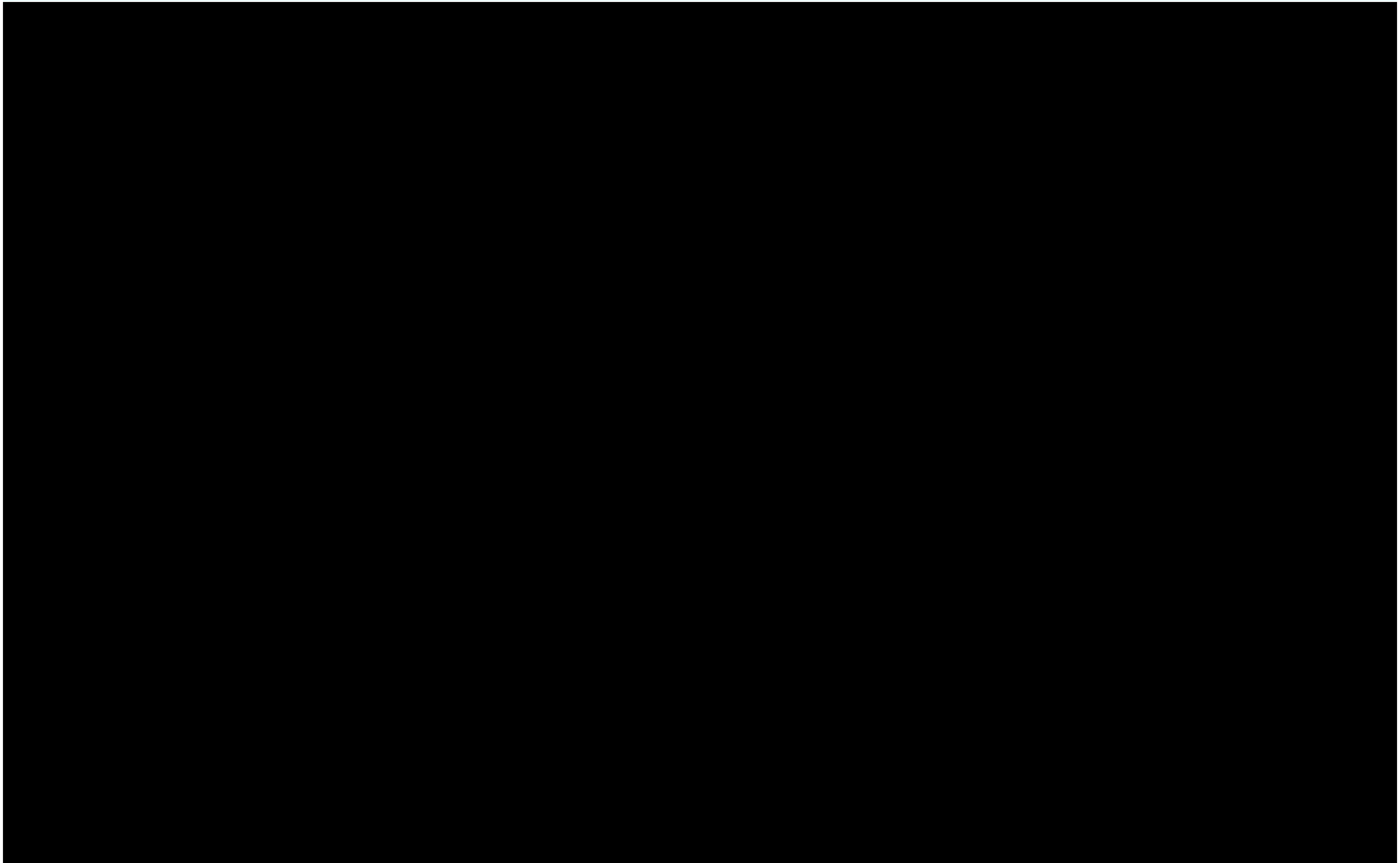
How to Achieve μg – Parabolic Flights

- The airplane manoeuvres without lift and compensating drag = only gravity
- Size and weight of experiments: large
- Power available: large
- Time: 25 sec, repeated up to 50 times
- Perturbations: 0.01 g
- Operators: investigators themselves
- Safety, accommodation etc. important

How to Achieve µg – Parabolic Flights

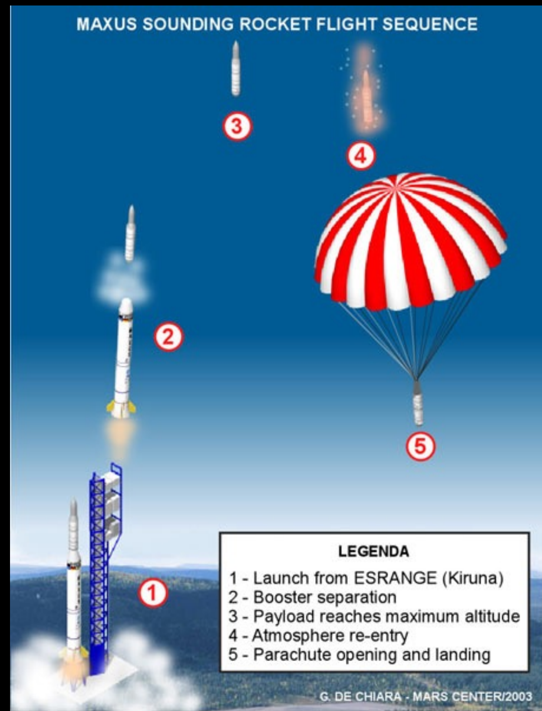


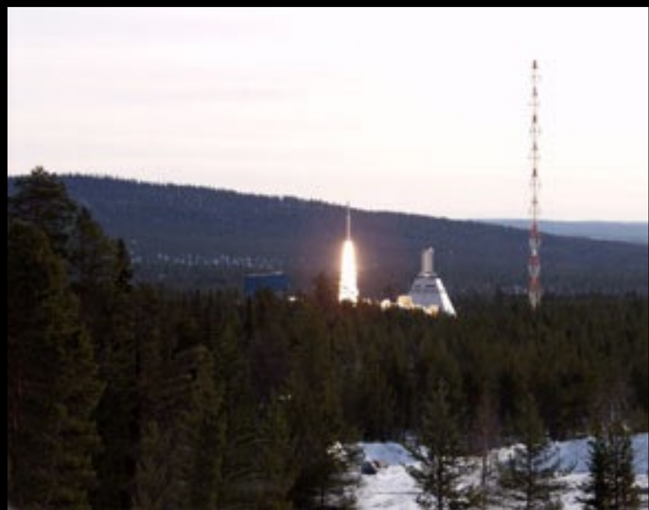
Vuelo estudiantes Nov2016



How to Achieve μg – rockets

- ESA System: Maxus
- Useful μ-g time: 12 minutes
- Maximum acceleration: 12g
  - Maximum altitude: 740 km
  - Launch location: Kiruna, sweden

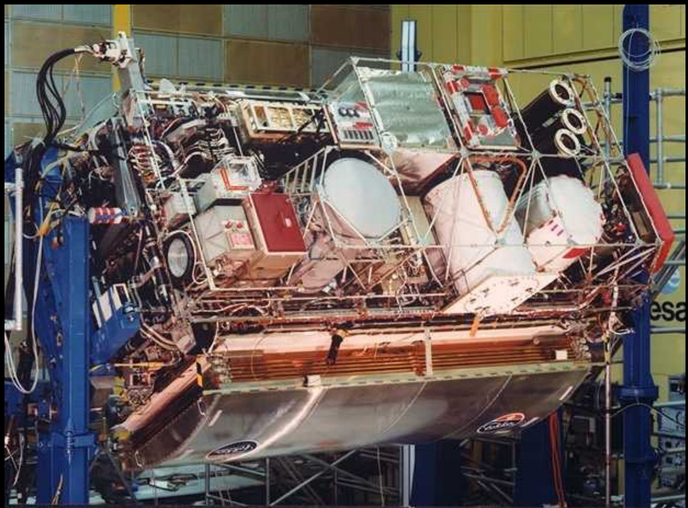


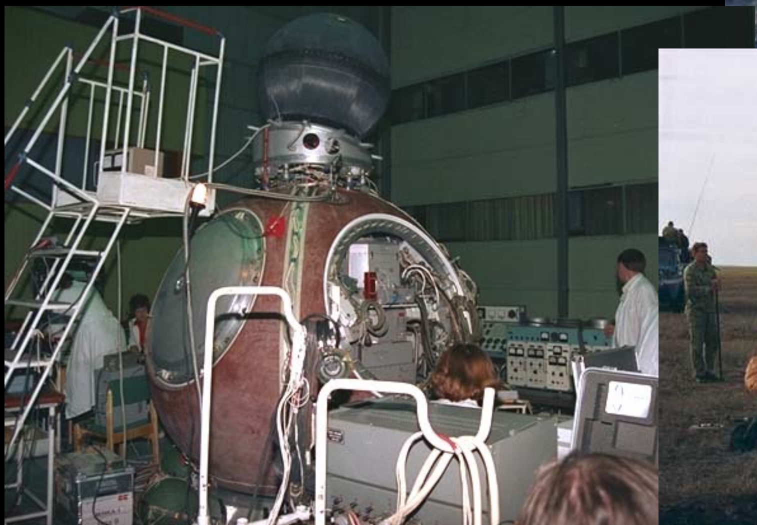


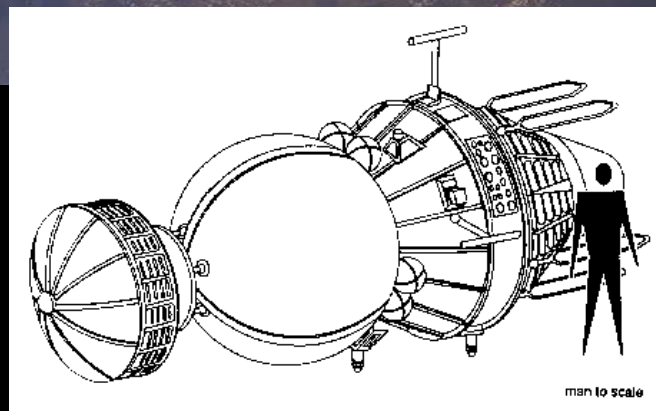
How to Achieve µg – Autonomous Satellites

- Autonomous Spacecraft with experiments
- Eureca
  - Went up and down with the Shuttle (1 year autonomous)
  - 1000 kg experiments, 1 kW
  - Used only one time in 1992
- Foton / Bion
  - Soyuz Rocket, return as a capsule (1 month)
  - 500 kg experiments, 400 W
  - Frequent use, Annually ESA campaigns

How to Achieve µg – Autonomous Satellites





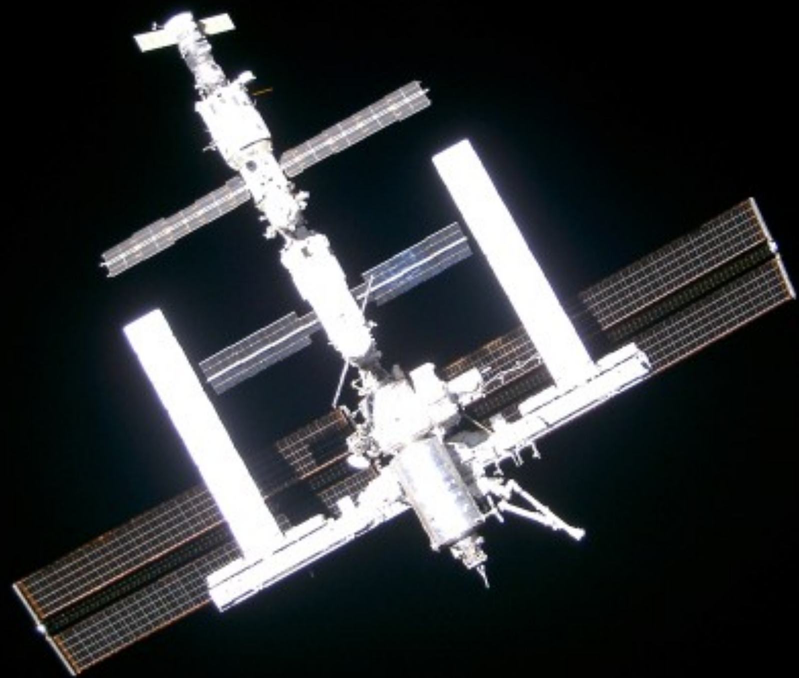


Typical On-Orbit Foton Configuration

How to Achieve µg – The Space Station

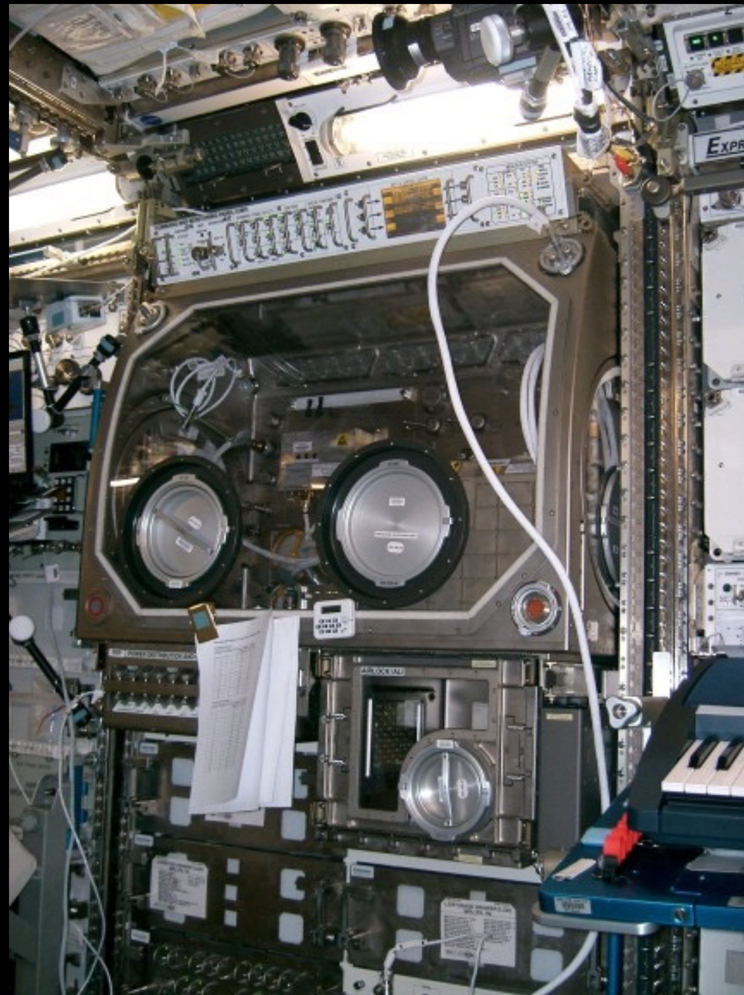
- Times: unlimited, up to months
  - Experiment size: up to 1 m3
  - Powerful energy supply and data transmission
  - Operators available for the equipment
- Other considerations
  - Crew safety, accommodation
  - Long design and development lead times
  - Equipment must be lifted up there
  - Comparisons with control samples must be made carefully (best: with on-board centrifugue)

How to Achieve µg – The Space Station



The ISS is Complete

How to Achieve µg – The Space Station



Different Characteristics

System	*Parabolic flight airplanes*	*Drop Towers*	*Sounding Rockets*	*Automatic Satellites*	*The Space Station*
Examples	Novespace Airbus NASA KC 135 NASA DC 9	NASA Glenn INTA Madrid ZARM Bremen JAMIC (J) MG-LAB (J)	Mini-TEXUS TEXUS MAXUS	EURECA Foton-Bion	MIR IML ISS
Zero-gravity time	20 s	2.2s - 10 s	Minutes	Weeks – months	Hours - months
Perturbations (g)	10 e-2 – 10 e-4	10 e-5 – 10 e-6	10 e-4 – 10 e-5	0,001	10 e-3 – 10 e-5
Manual Access	Yes	No (yes between drops)	No	No	Yes
¿Automatic?	Recommended	Compulsory	Recommended	Compulsory	Recommended
Telemetry / telecommands	No	Yes	Yes	Yes (intermittent)	Yes (intermittent)
Campaigns	2/year	Daily	1 - 2/year	Irregular	Irregular
Flexibility for changes	Low	High	No	No	Low
In-situ help	No	Yes	No	No	Yes

Conclusions

- Experimentation in microgravity is a tool of ample use in Science
- There are a number of systems to achieve it with different prices and characteristics
- A complete Space Station is already fostering significant advances in Science