THE BREMEN DROP TOWER

A STEPPING STONE TO LOW EARTH ORBIT

Dezember 08, 2015

NANORACKS ISS WORKSHOP, LEIDEN, NL

Dr. Thorben Könemann

ZARM Drop Tower Operation and Service Company

WWW.ZARM.UNI-BREMEN.DE

Universität Bremen*

*EXZELLENT.
Gewinnerin in der
Exzellenzinitiative

CENTER OF
APPLIED SPACE TECHNOLOGY
AND MICROGRAVITY

ZARM

ZARM‘s Organization Structure

founded in 1985

ZARM - Center of Applied Space Technology and Microgravity

c/o University of Bremen
Am Fallturm, 28359 Bremen, Germany
www.zarm.uni-bremen.de

ZARM - University of Bremen

Research Institute - Faculty 04 Production Engineering

Prof. Dr. Claus Lämmerzahl
(Executive Director)

Prof. Dr. Claus Lämmerzahl
(Director Space Science)

Prof. Dr. Claus Braxmaier
(Director Space Technology)

- to be announced -
(Director Fluid Dynamics)

ZARM FAB mbH

ZARM Drop Tower Operation and Service Company

Prof. Dr. Claus Lämmerzahl
Peter von Kampen
(Executive Board)

Christian Eigenbrod
Dr.-Ing. Thorben Könemann
Ulrich Kaczmarczik
(Scientific / Technical Management)

ZARM Technik AG

Supplier of Attitude Control Equipment for Satellites

Holger W. Oelze
(Chief Executive Officer)

Peter von Kampen
(Chief Financial Officer)

Marco R. Fuchs
(Chairman of Supervisory Board)

- Research / Teaching
- Technical Support
- Space Hardware

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ZARI

Supplie Equipn

Holge (Chief

Peter (Chief

Marc (Chair

- technical support for microgravity experiments
  - payload integration service since 1990
  - qualification and testing
  - competent and well-experienced engineers

- Research / Teaching
- Technical Support
-

ZARM‘s Student Programs

Support of Young

ZARM - Center of Applied Space Technology and Microgravity

c/o University of Bremen
Am Fallturm, 28359 Bremen, Germany
www.zarm.uni-bremen.de

DropTES
- UNOOSA -

Drop Tower Experiment Series

UNITED NATIONS
Office for Outer Space Affairs

- Bremen Drop Tower

Drop Your Thesis!
- ESA Education Office -

Drop Tower Experiment Series

esa

- Bremen Drop Tower

REXUS / BEXUS
- DLR / SNSB -

Sounding Rocket and Ballon Experiment Series

DLR

RYMDSTYRELSEN
Swedish National Space Board

- Esrange Space Center
Kiruna, Sweden

DropPS
- ZARM -

Drop Tower Project for School Students
- DLR_School_Lab -

ZARM

ZARM TEST CENTER - we.know.h

know-how, reliability, flexibility, customer-focused

- Convenient Combination of ZARM's Test Labs
  - Aerospace Qualification and Test Services under one roof

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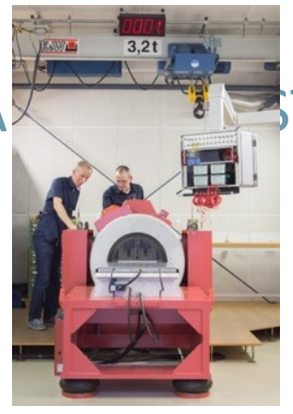

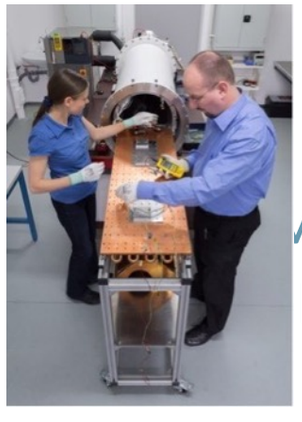

MA R / CYC

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ZARM

ZARM TEST CENTER - we.know.how.

know-how, reliability, flexibility, customer-focused

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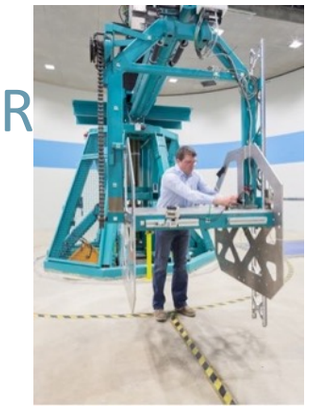
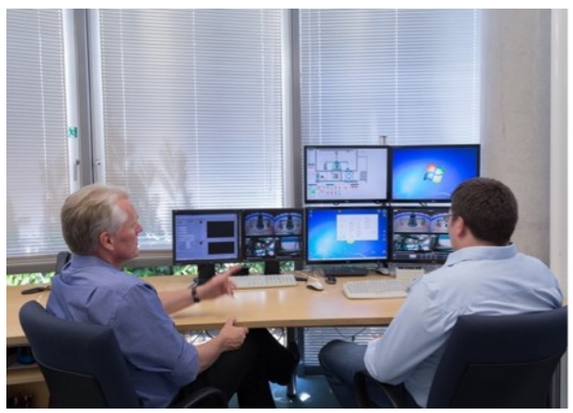




ZARM TEST CENTER - Team

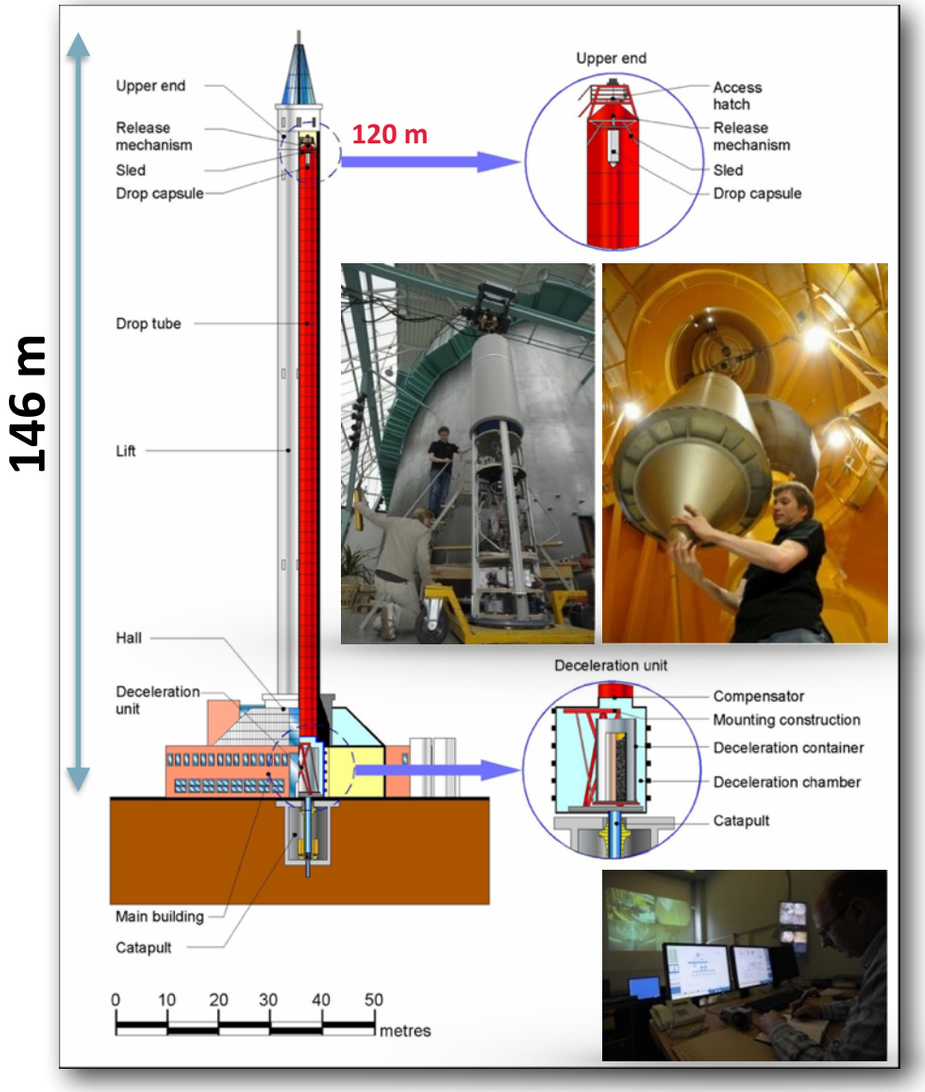
ZARM

Content

- The Bremen Drop Tower
  - Introduction
  - Operation
  - Facts and Figures
- Examples: Drop Tower Experiments
- Scientific Pathfinder Flights
  - XCOR Aerospace: Lynx Mark I
  - End-to-End Service

The Bremen Drop Tower - Introduc

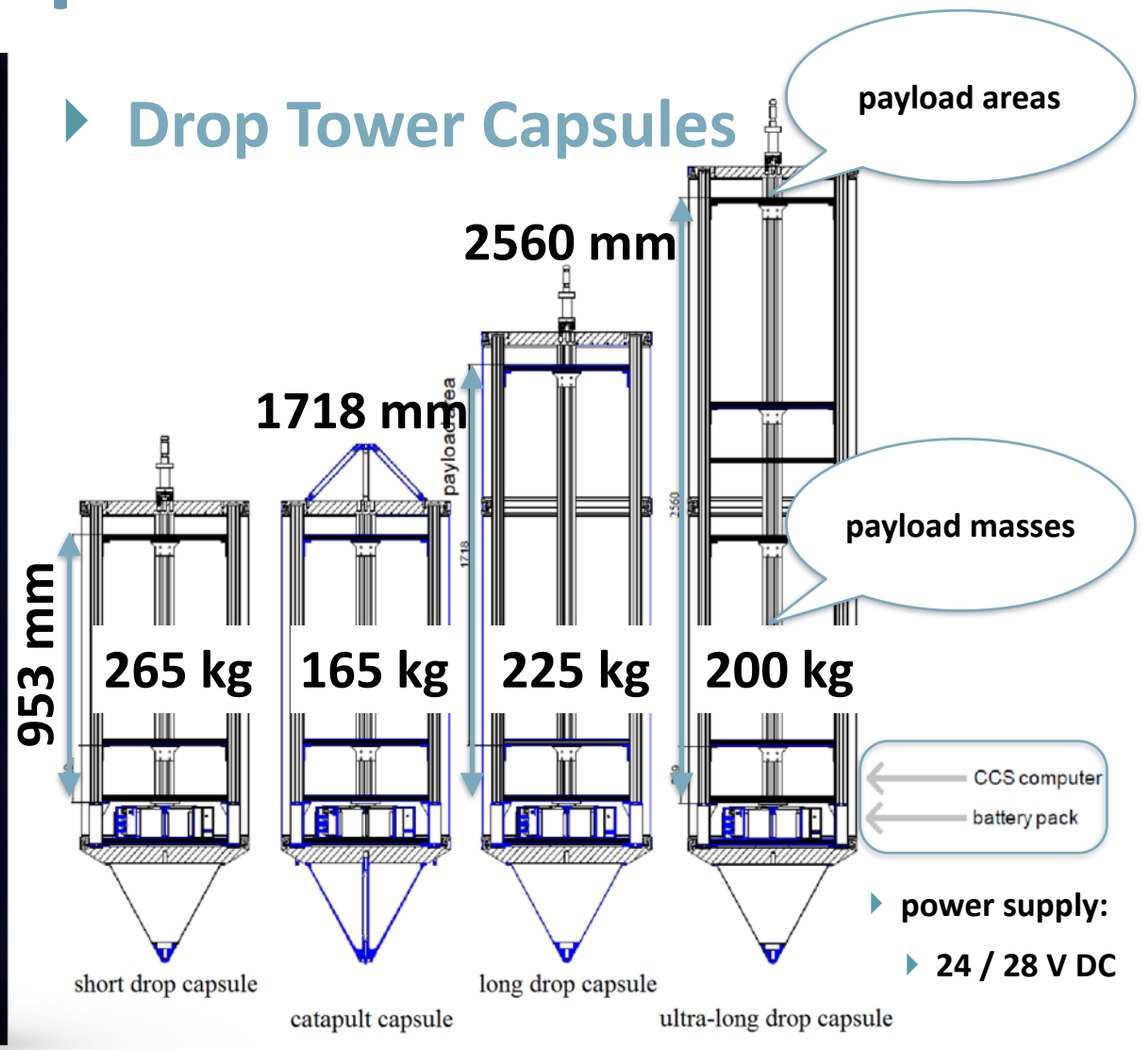
operation started



- drop mode:
  - 4.74 s in weightlessness
  - highest quality - 10^{-6} g (µg)
  - decelerations of up to 50 g
- catapult mode:
  - worldwide unique facility
  - 9.3 s in weightlessness
  - highest quality - 10^{-6} g (µg)
  - accelerations of up to 30 g

The Bremen Drop Tower - Introduction

Drop Tower Capsules

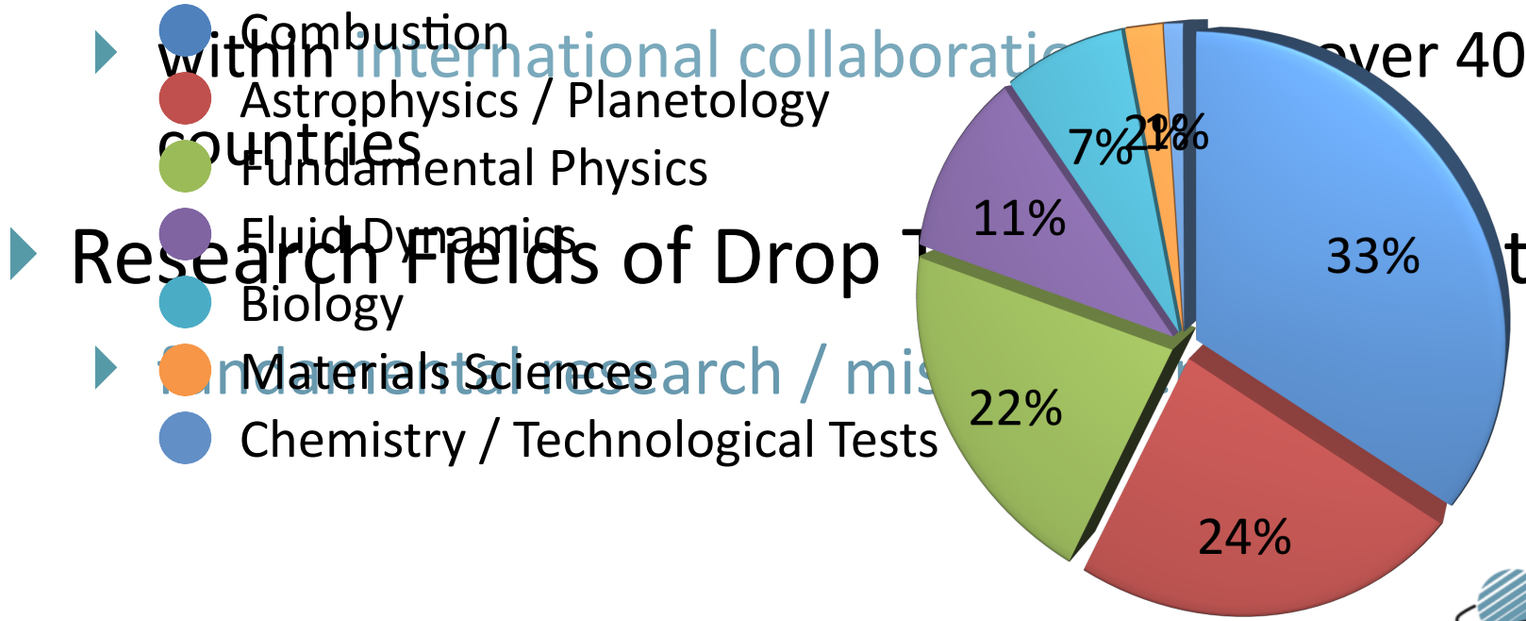


- **power supply:**
  - **24 / 28 V DC**

The Bremen Drop Tower - Operation

The Bremen Drop Tower - Facts and

- Since the Start of Operation in 1990
  - over 7500 drops / catapult launches have been conducted
  - more than 200 different experiment types have been integrated
  - within international collaboration over 40 countries
- Research Fields of Drop Tower Experiments
  - fundamental research / mission preparation



The Bremen Drop Tower - Facts and

- Scientific Access to the Bremen Drop Tower
  - National Research Program
    - supported by German Aerospace Center (DLR)
    - via DLR Space Administration
      -> Microgravity Research and Life Sciences Program
  - European Research Program
    - supported by European Space Agency (ESA)
    - via ESA Human Spaceflight and Exploration
      -> Continuously Open Research Announcement (CORA)
  - International Research Cooperations / Bilateral Collaborations

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Fundamental Physics - QUANTUS I / II

- Ultracold Macroscopic Quantum Systems in Weightlessness - Drop Tower
  - supported by DLR Space Administration
    - QUANTUS - Collaboration / U Hanover, Berlin, Bremen, Hamburg, etc.

Related Publications:
- T. van Zoest et al., Science 328 (2010)
- H. Müntinga et al., Phys. Rev. Lett. 110 (2013)
- J. Rudolph et al., New J. Phys. 17 (2015)

- Realization of first Bose-Einstein Condens
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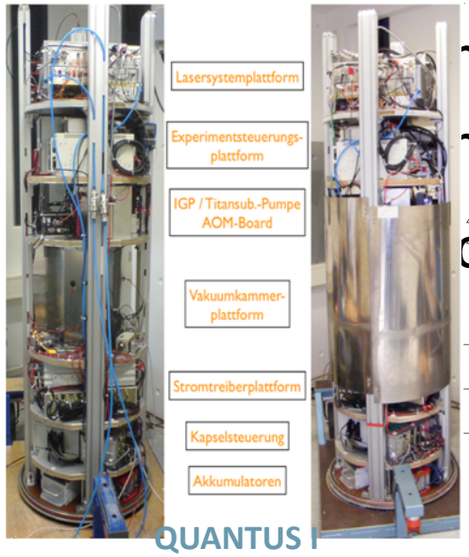
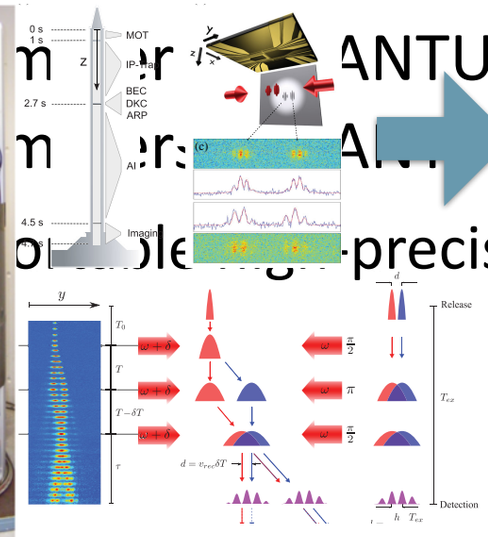
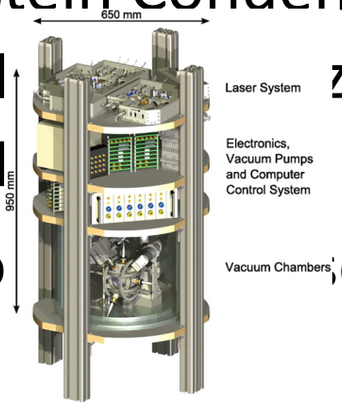


QUANTUS I





QUANTUS II
- Catapult Experiment -

- MAIUS - Sounding Rocket Experiment, 2016

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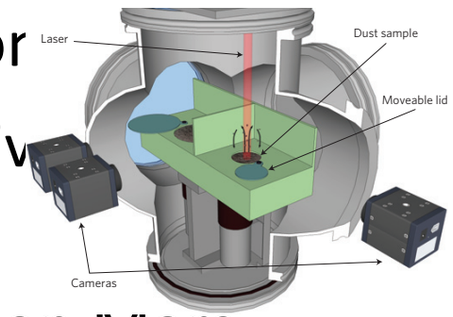
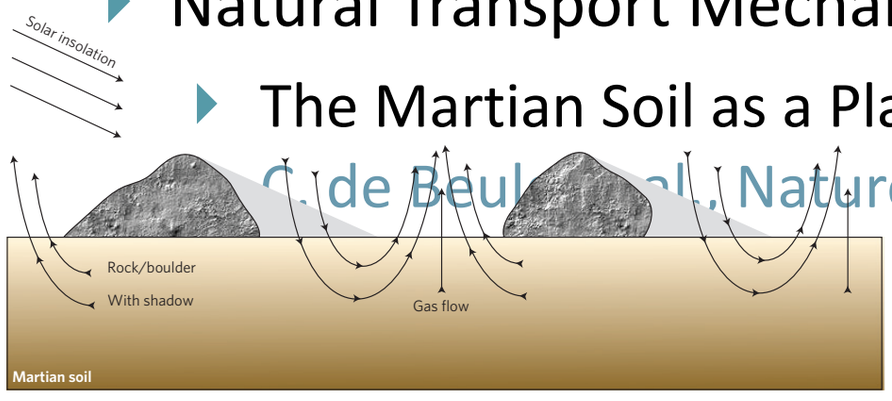
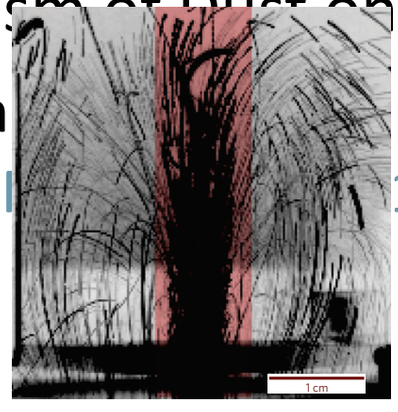
Astrophysics - EULE

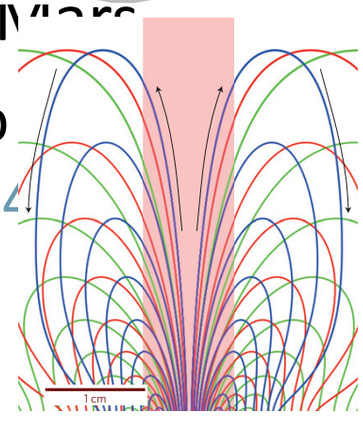
- Experimental Investigation of Light-Induced Eruptions in Microgravity - Drop Tower Experiments
  - supported by DLR Space Administration
    - Experimental Astrophysics Group, Univ Duisburg-Essen



- Natural Transport Mechanism of Dust on Mars
  - The Martian Soil as a Plan p
    - C. de Beul al., Nature I 14







EULE
- Catapult Experiment -

Combustion - DDI-ADL

- Investigation of Droplet-Droplet Interaction utilizing the Advanced Disc Laser - Drop Tower Experiments
  - supported by DLR Space Administration
    - Combustion Engineering Group, ZARM, Bremen
  - Lowering the Emissivity of harmful Ni
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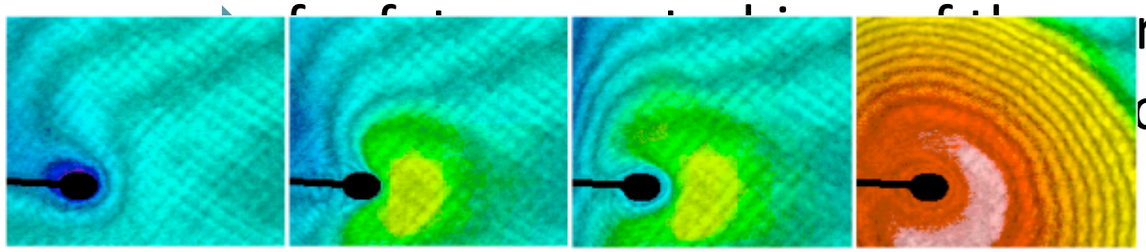
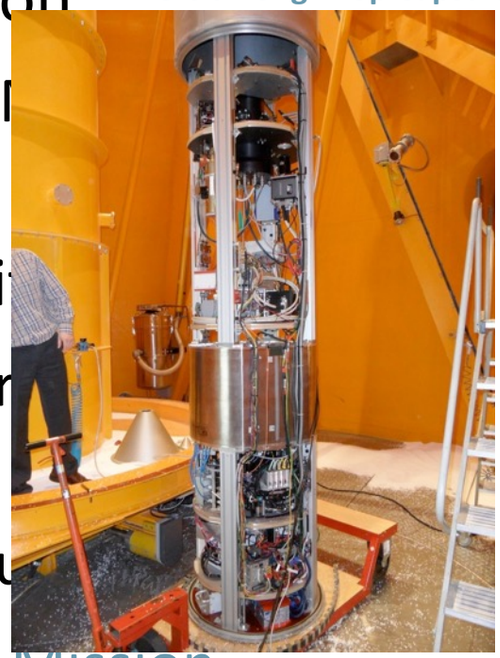
  - 1.4.3 more - LEXUS Sounding Rocket Mission



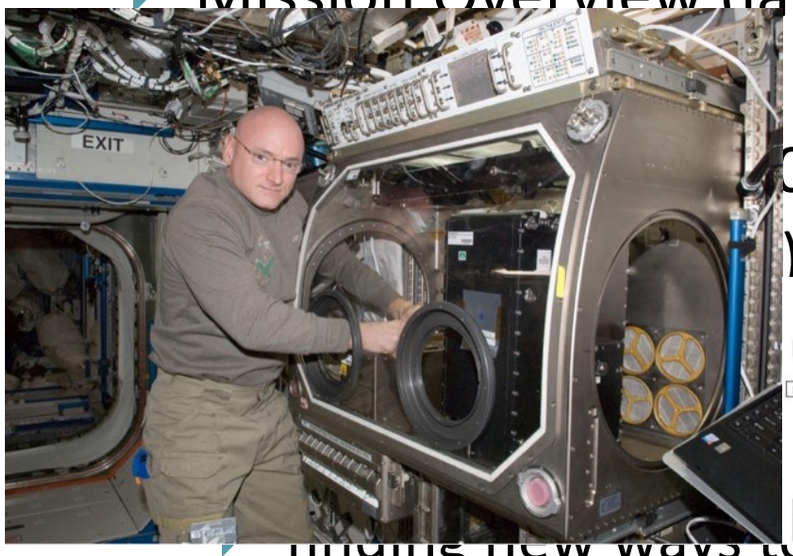
Laser-Induced Fluorescence Spectroscopy (ADL)

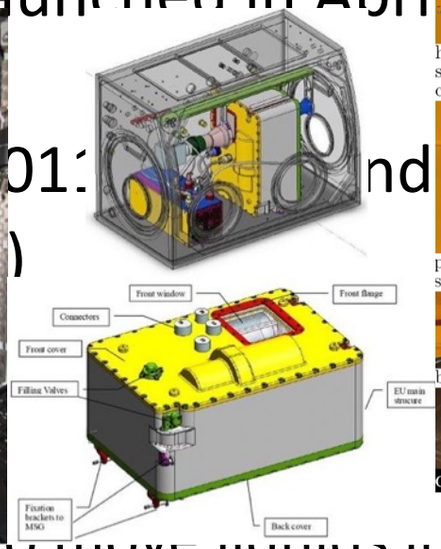
Ultra-Long Drop Capsule



Fluid Dynamics - CCF (Mission Preparation)

- Capillary Channel Flow - Experiment onb ISS
  - US - German Partnership ISS Mission by NASA
    - ZARM - University of Bremen / Portland State University
  - Mission Overview (launched in Apri stalled
    - 01: nd
    -)
    - finding new ways to move liquids in space

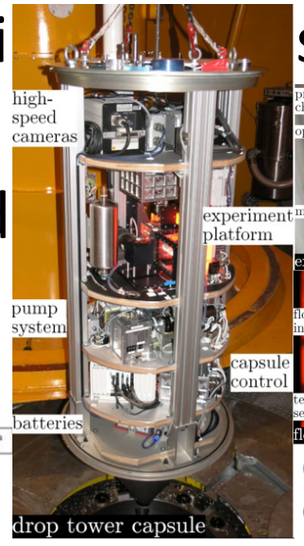


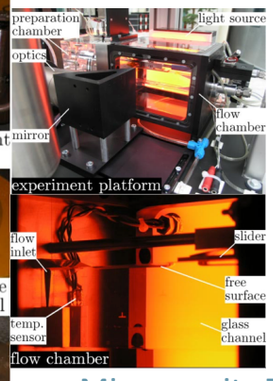


NASA

Sounding Rocket Missions:
Parabolic Flight Missions
- CCF on TEXUS 37 (2000)
- CCF on TEXUS 41 (2004)
- CCF on TEXUS 42 (2005)

Drop Tower Experiments



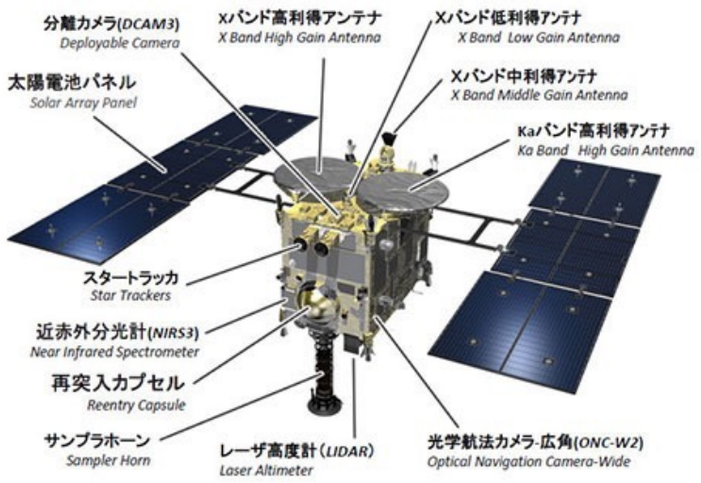


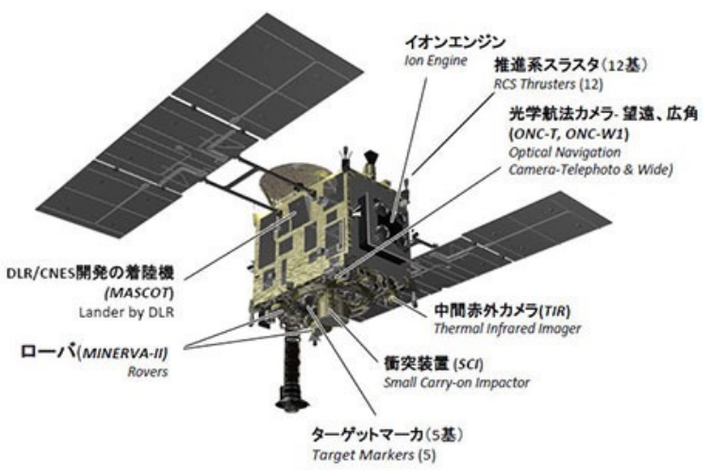
e.g. Microgravity Tests of Channel Geometries

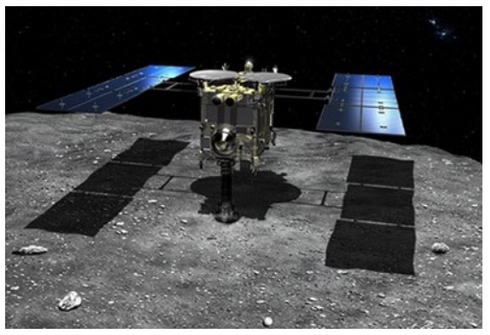
Preparation of Space Missions - Peregrine Falcon

- Asteroid Explorer Mission (Target: Asteroid Ryugu)
  - Japanese Satellite Mission by JAXA
    - in Cooperation with DLR and CNES (MASCOT - Lander)
  - Mission Overview (Successor of Hayabusa - launched in May 2003 / landed on Asteroid Itokawa in Nov.

first return of asteroidal material back



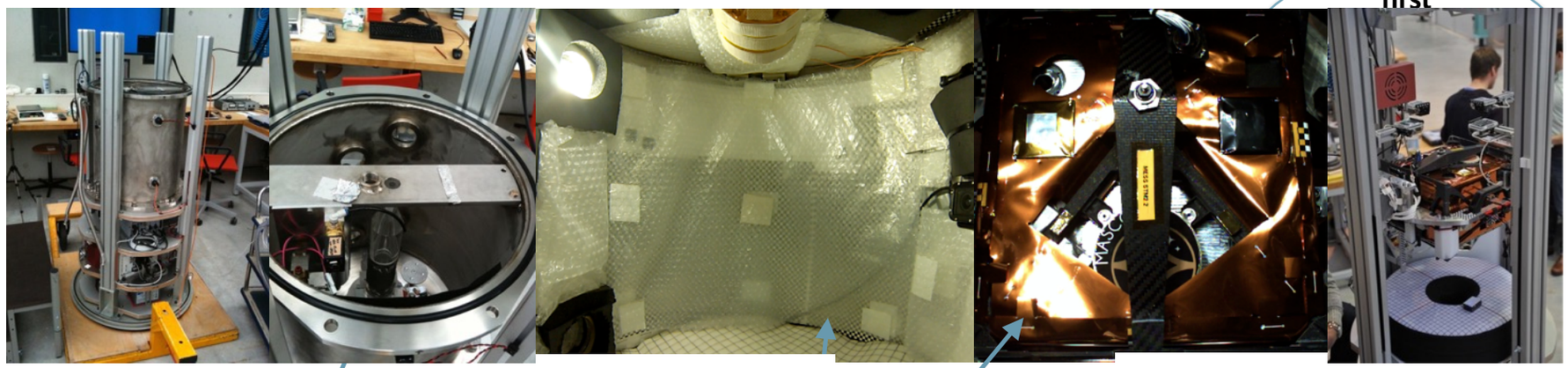




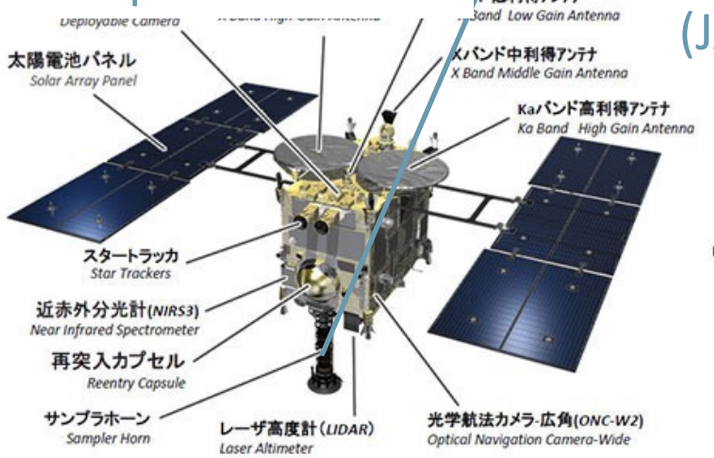
JAXA

Preparation of Space Missions - Peregrine Falcon

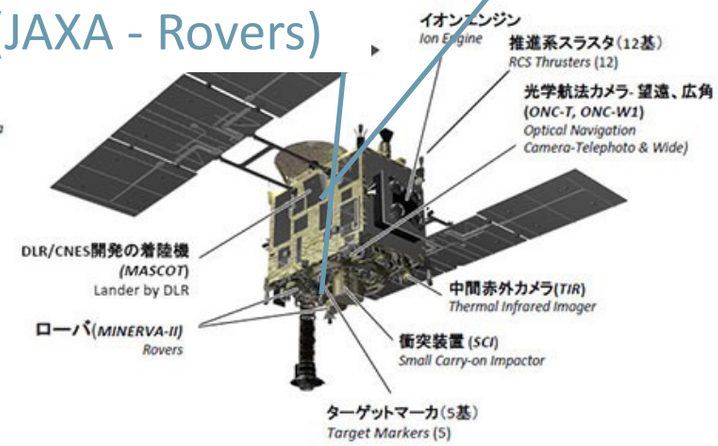
- Asteroid Explorer Mission (Target: Asteroid



Sampler Horn Tests 2003 Deployment Tests eroid Itoka Separation Tests



(JAXA - Rovers)



(DLR - Lander)

JAXA

Preparation of Space Missions -

- Gravity Recovery and Climate Experiment Follow-On
  - US - German Partnership Satellite Mission by
    - NASA/JPL and the German Research Center for Geosciences (GFZ)

(Center for Space Research (CSR) / University of Texas, DLR, ion CE -
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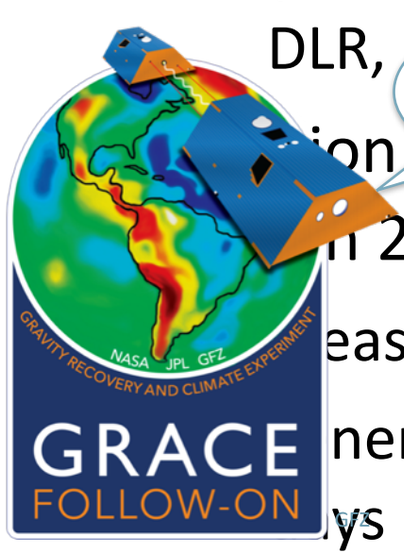
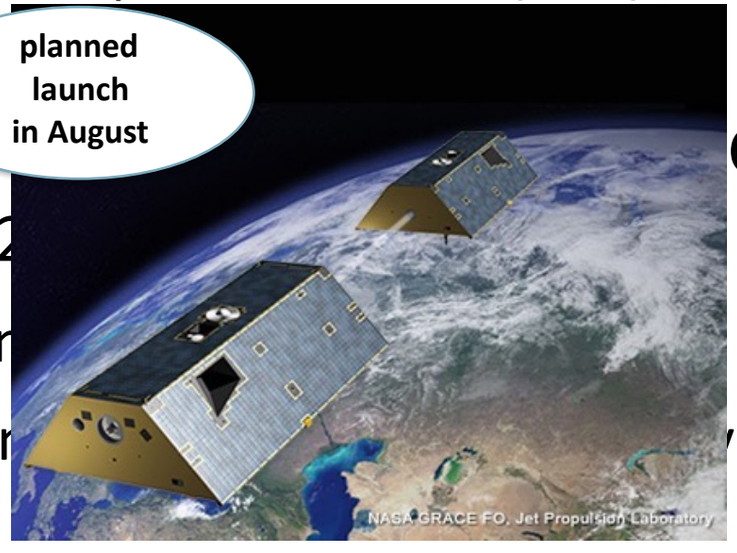
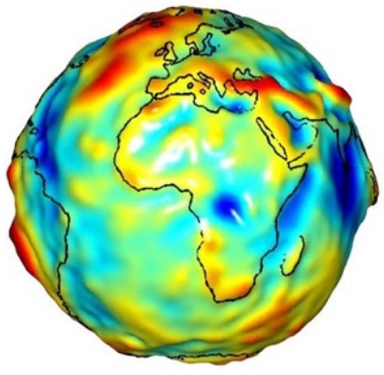




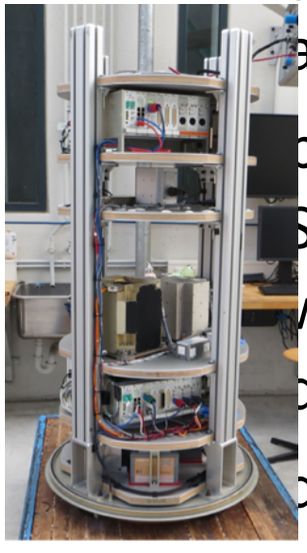


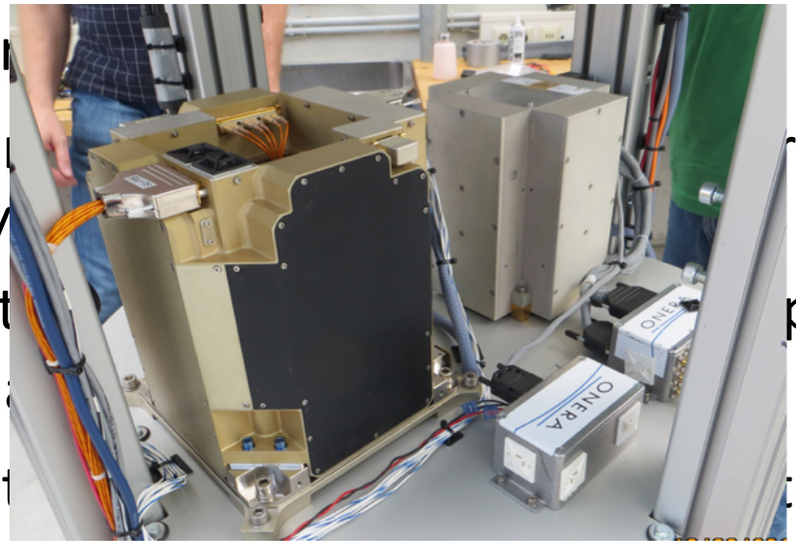
NASA GRACE, Jet Propulsion Laboratory

Preparation of Space Missions -

- Gravity Recovery and Climate Experiment Follow-On
  - Mission Preparation at the Bremen Drop Tower
    - GRACE-FO - scientific instrument: accelerometers by ONERA

(Office national d'études et de recherches aér





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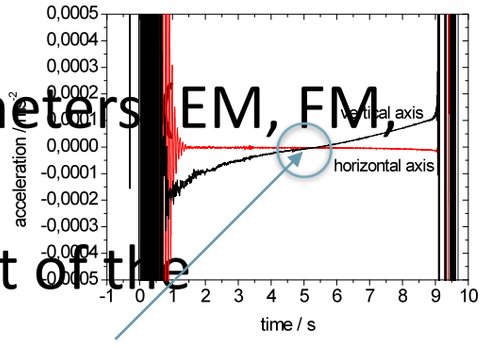

turning point of catapult capsule

- v = 0 / a = 0

det test mass positioning

Preparation of Space Missions -

- Gravity-Research Micro-Satellite Mission
  (Micro-Satellite à traînée Compensée pour l'Observation du Principe d'Equivalence)
  - French Satellite Mission by CNES / in Cooperation with ESA
    - in Cooperation with ONERA, the Observatoire de la Côte d'Azur (OCA), ZARM, and the National Metrology
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      sic launch in April 201
      es nce Principle down t
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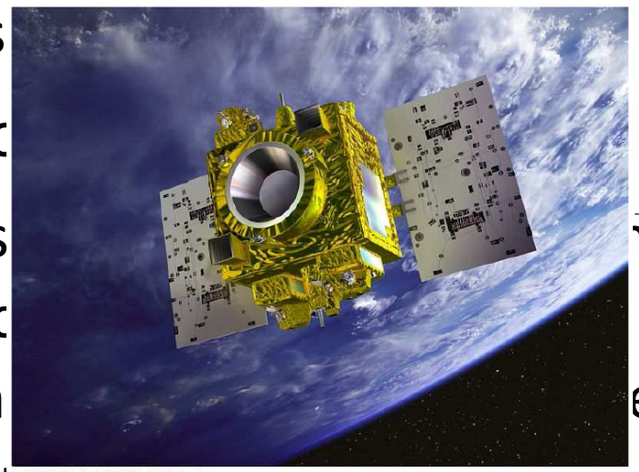

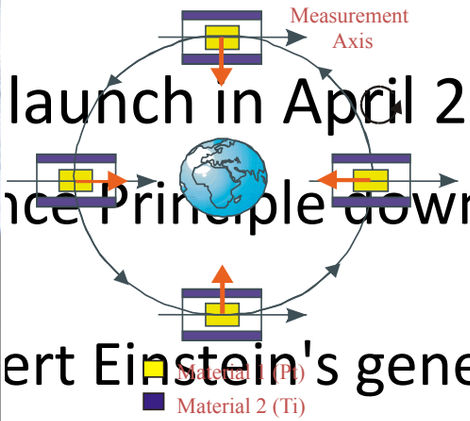

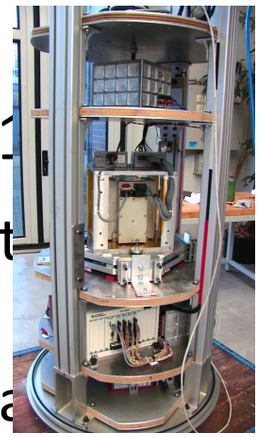

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Scientific Pathfinder Flights

- SPF - Payloads - Lynx Mark I

2x suborbital flights
< 1 min under µg

- EUPHORIE (U Duisburg-Essen)
- Service Module (Payload A)
- Exp. (Payload B)
- EQUIPAGE (OVGU Magdeburg)
- Daphnia (U Bayreuth)

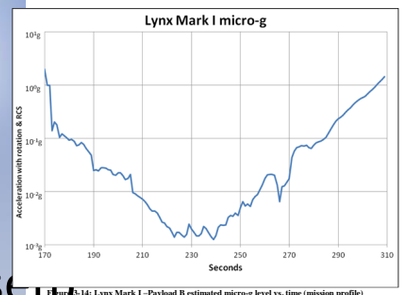
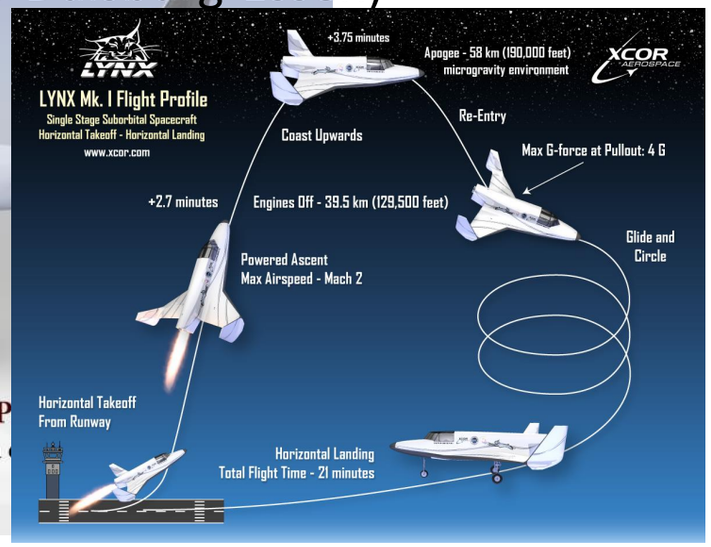


Figure 3-14: Lynx Mark I –Payload B estimated micro-g level vs. time (mission profile)



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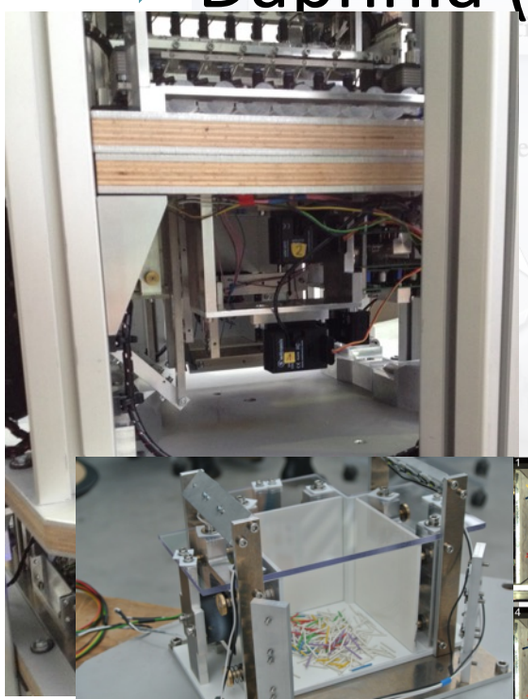
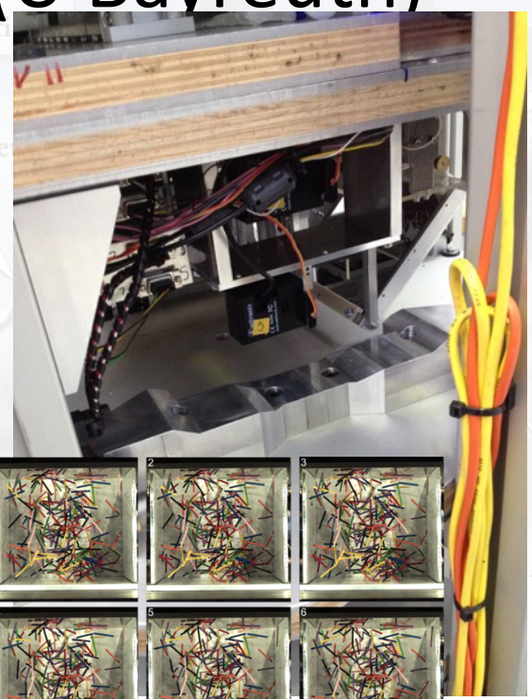
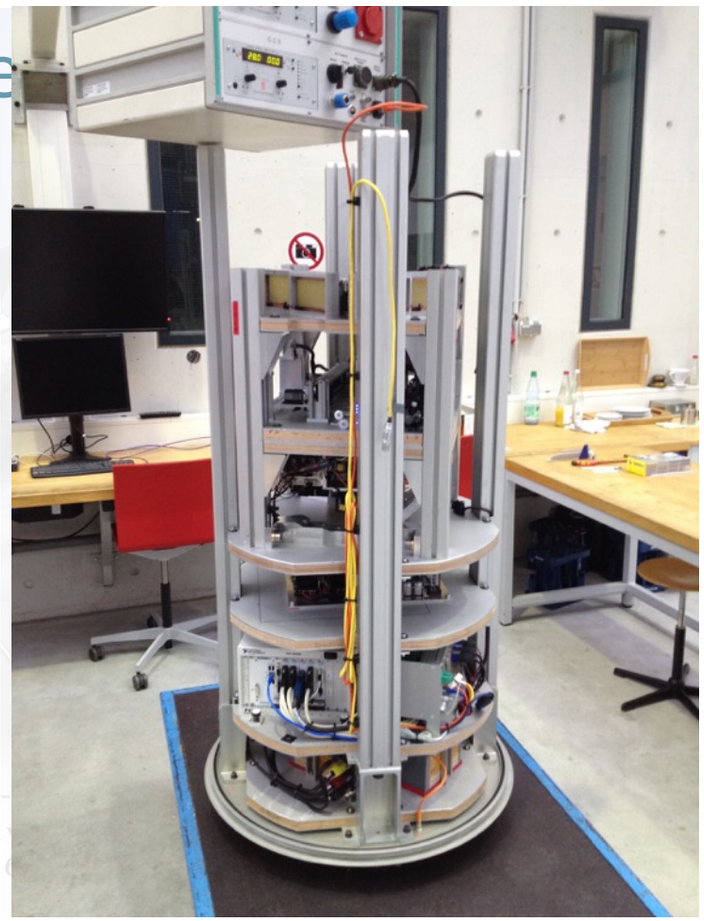
Scientific Pathfinder Flights

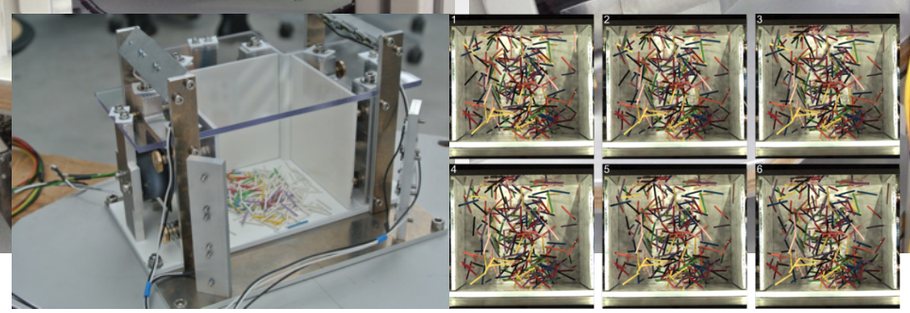
- Drop Tower Campaigns - Lynx Mark I
  - EQUIPAGE (OVGU Magde
  - Daphnia (U Bayreuth)

Payload B



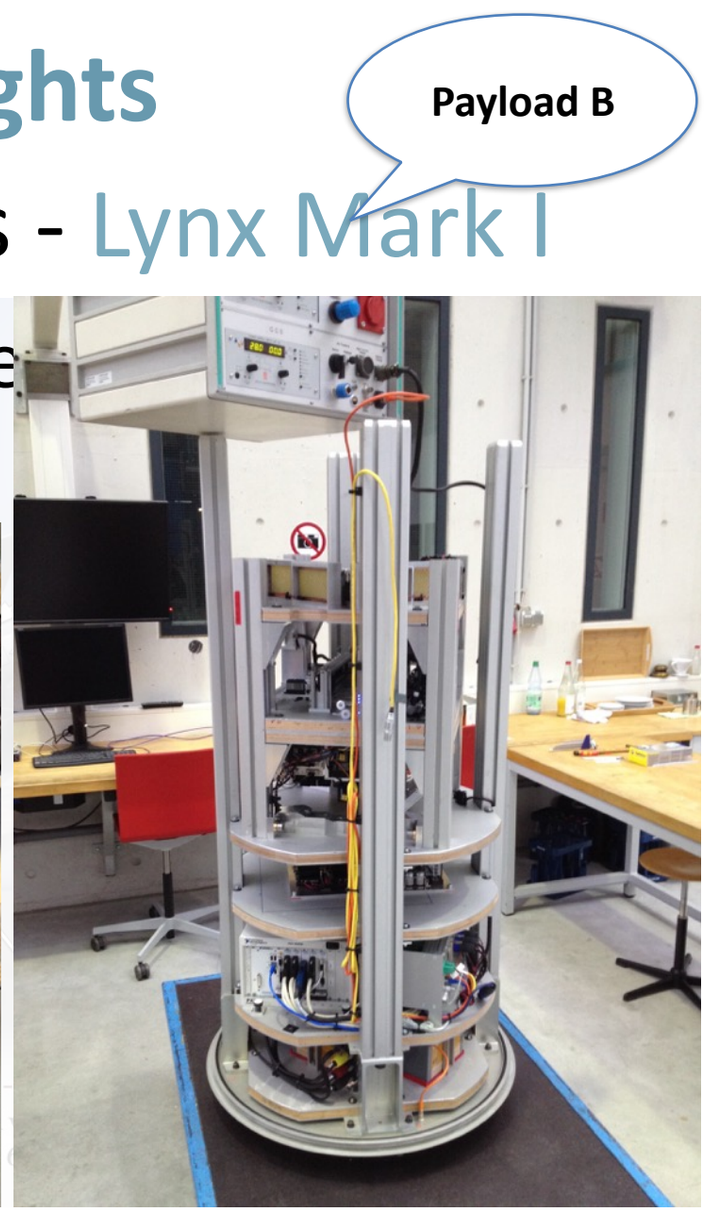




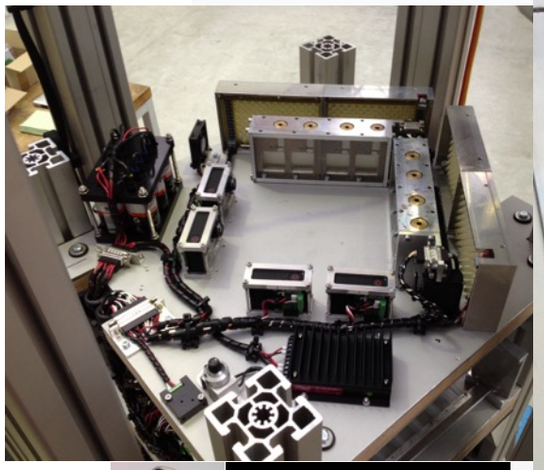


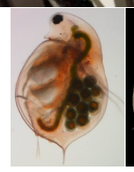
Scientific Pathfinder Flights

- Drop Tower Campaigns - Lynx Mark I



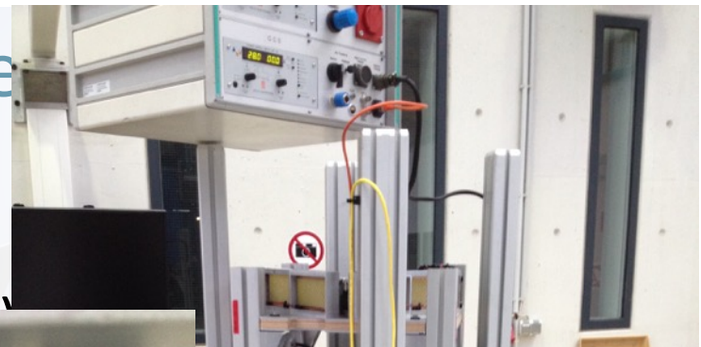
  - EQUIPAGE (OVGU Magde
  - Daphnia (U Bayreuth)

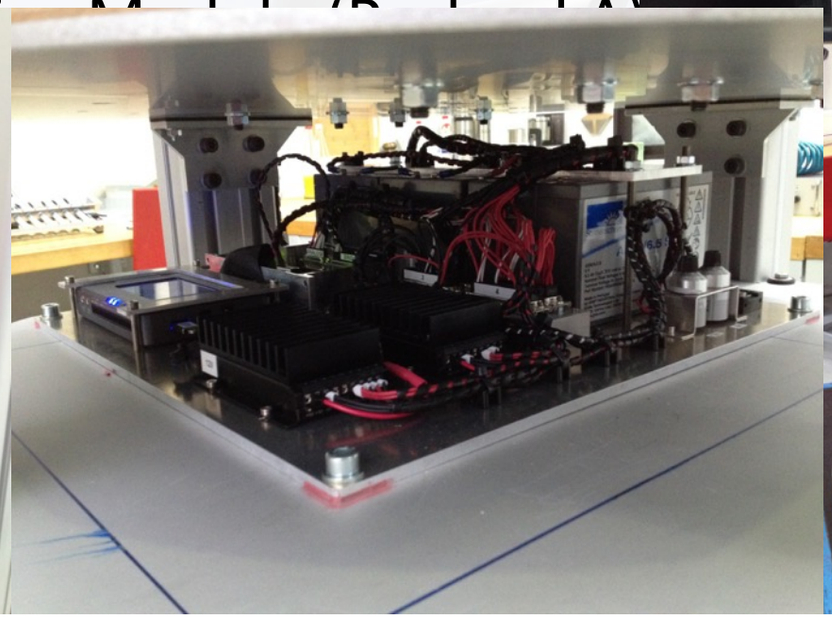


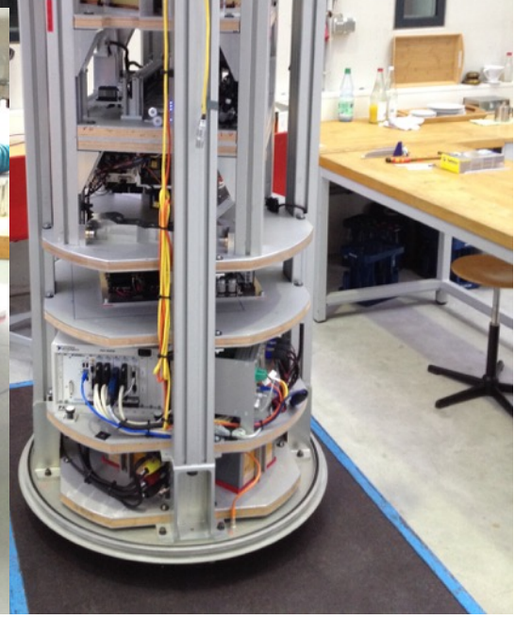


Scientific Pathfinder Flights

- Drop Tower Campaigns - Lynx Mark I
  - EQUIPAGE (OVGU Magde
  - Daphnia (U Bayreuth)





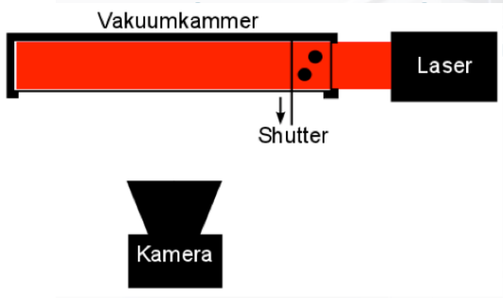


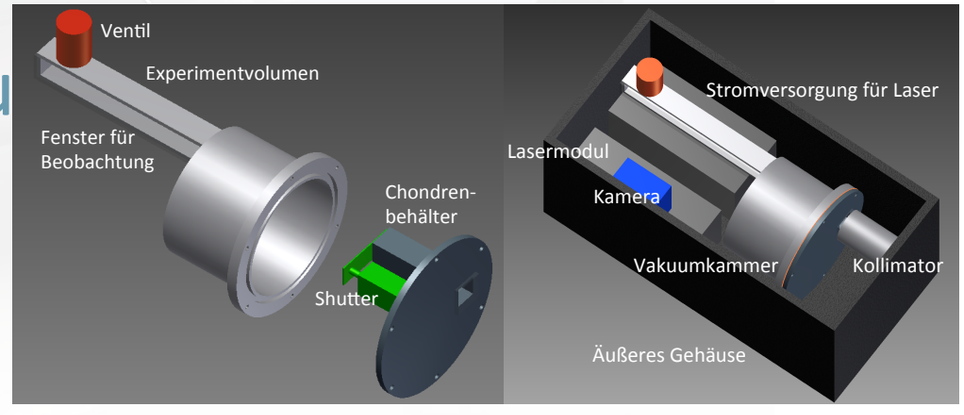
Scientific Pathfinder Flights

Payload CP / CS

- Drop Tower Campaigns - Lynx Mark I
  - EQUIPAGE (OVGU Magdeburg)
  - Daphnia (U Bayreuth)
  - EUPHORIE (U Duisburg-Essen)

- Drop Tower Tests - done





- Experimental Investigation of Photophoretic Motion of Chondrules

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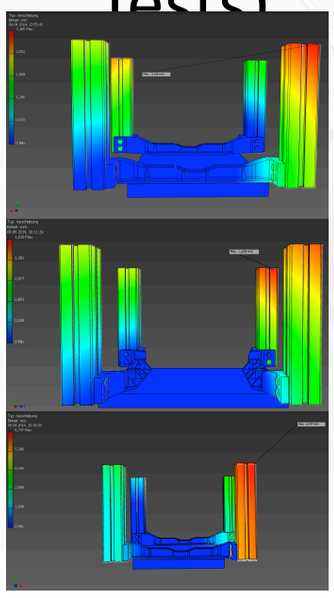
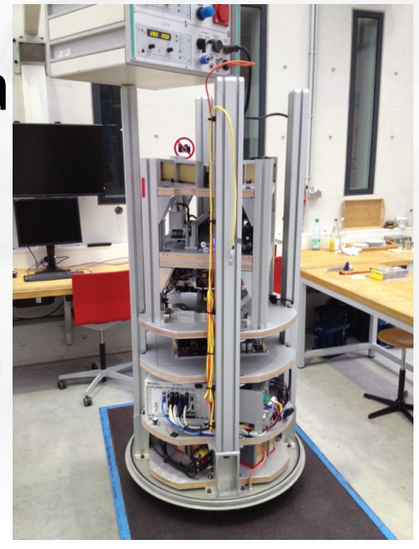
Scientific Pathfinder Flights

- End-to-End Service (Flight Tick
  - Development of a Service Module / Hardwa
  - Experiment Integration / Technical Support
  - Mission Preparation (Drop Tower / Qualification Tests)

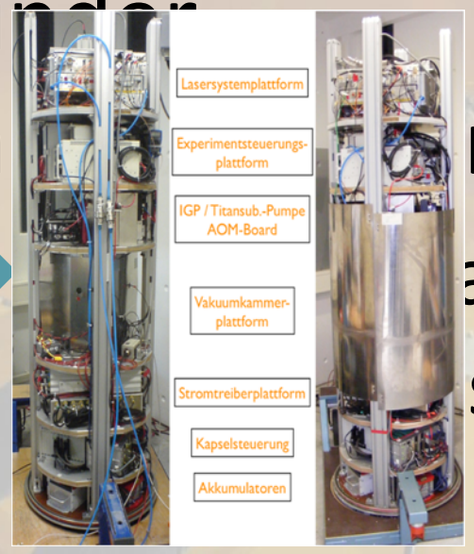
Content

- The Bremen Drop Tower
  - Introduction
  - Operation
  - Facts and Figures
- Examples: Drop Tower Experiments
- Scientific Pathfinder Flights
  - XCOR Aerospace: Lynx Mark I
  - End-to-End Service

Conclusion I

- The Bremen Drop Tower is an excellent platform
  for conducting short-term experiments under
  h m ty s
  al d
  s

QUANTUS I



QUANTUS II

DDI-ADL

- science at the Bremen Drop Tower

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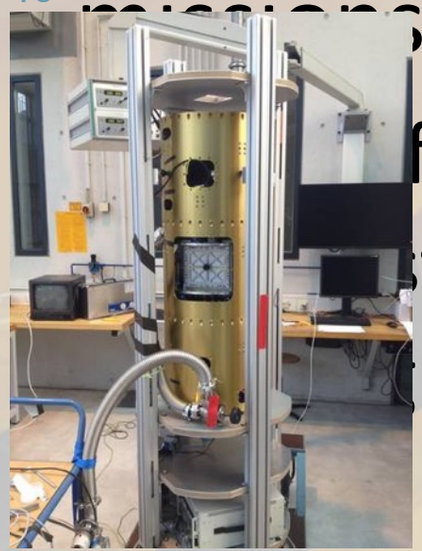
Conclusion II

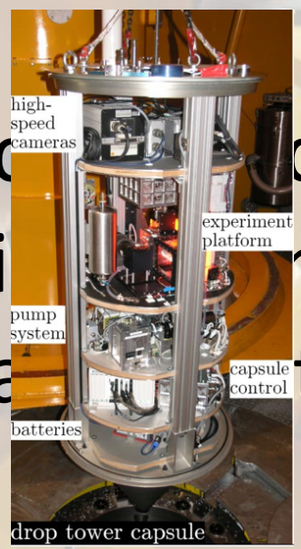
- The Bremen Drop Tower is an excellent platform
  for preparing a variety of space missions

µg-ESL - DLR MP



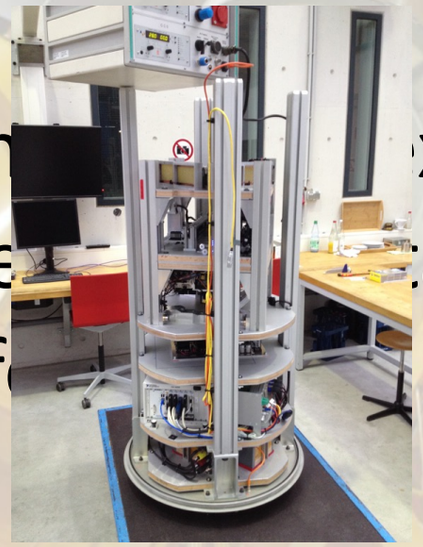
MAPHEUS - Sounding Rocket
Experiment Preparation

CCF - ZARM



ISS - Low Earth Orbit
Experiment Preparation

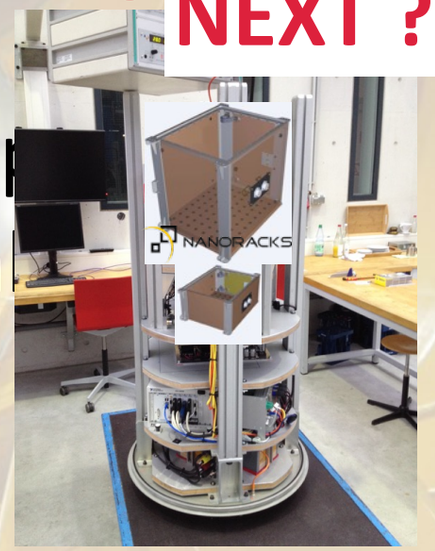
DLR - Scientific Pathfinder Flights



Lynx - Suborbital Flights
Experiment Preparation

Blue Origin

NEXT ?



New Shepard - Suborbital Flights
Experiment Preparation ???

- parameter definitions / evaluations, hardware / technology tests

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THANK YOU VERY MUCH FOR YOUR ATTENTION

ACKNOWLEDGEMENTS

DLR

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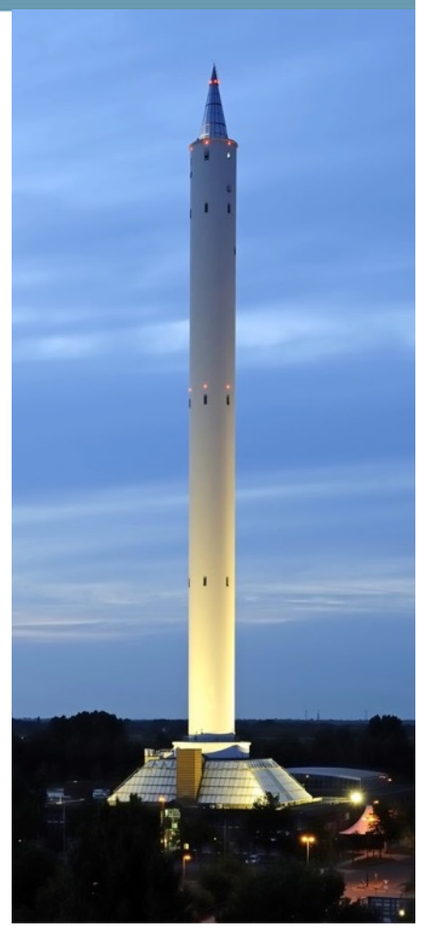
esa



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