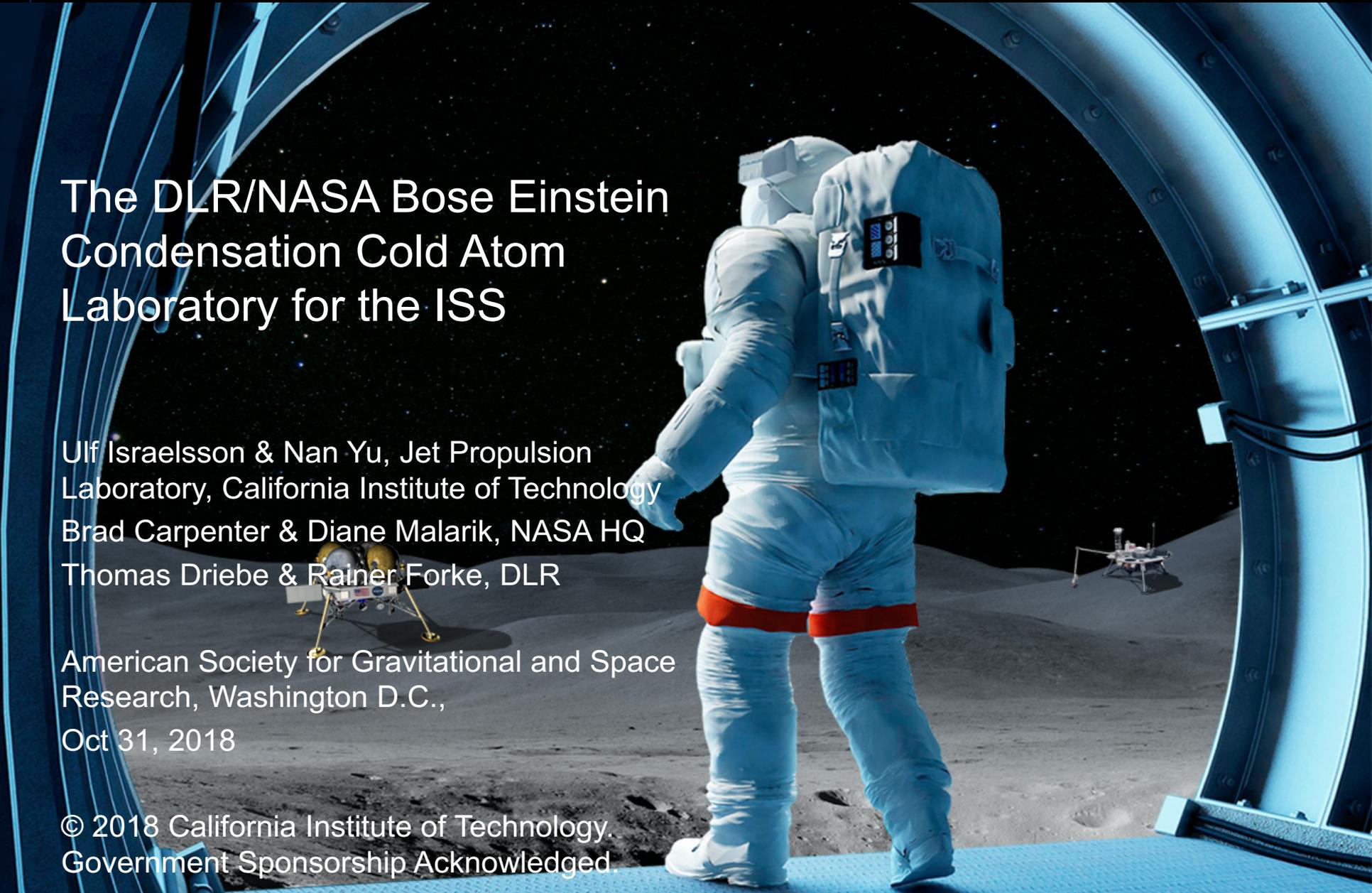


The DLR/NASA Bose Einstein Condensation Cold Atom Laboratory for the ISS

Ulf Israelsson & Nan Yu, Jet Propulsion
Laboratory, California Institute of Technology
Brad Carpenter & Diane Malarik, NASA HQ
Thomas Driebe & Rainer Forke, DLR

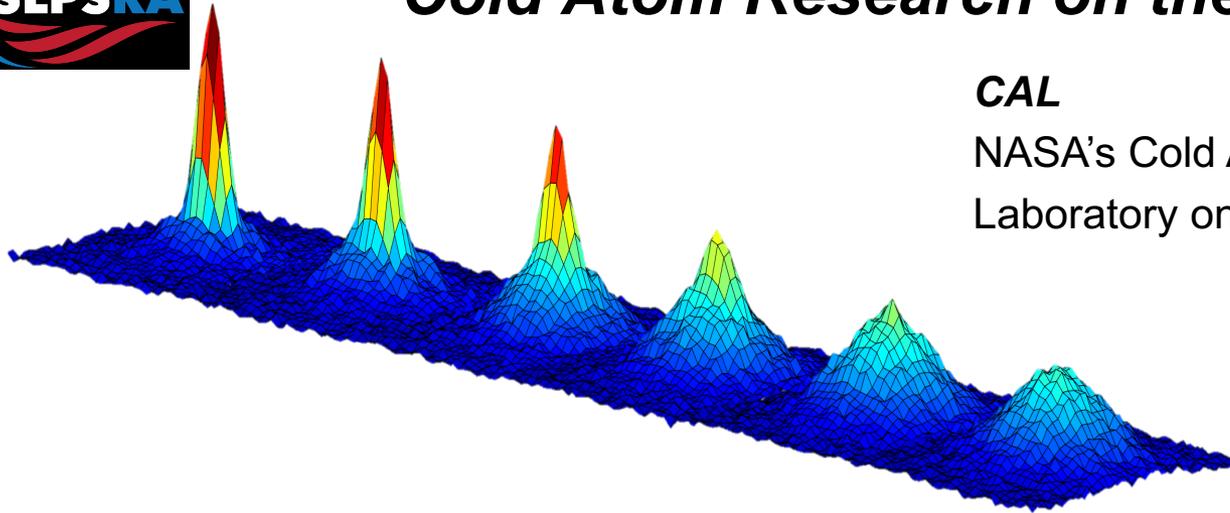
American Society for Gravitational and Space
Research, Washington D.C.,
Oct 31, 2018

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Government Sponsorship Acknowledged.





Cold Atom Research on the ISS



CAL
NASA's Cold Atom
Laboratory on the ISS

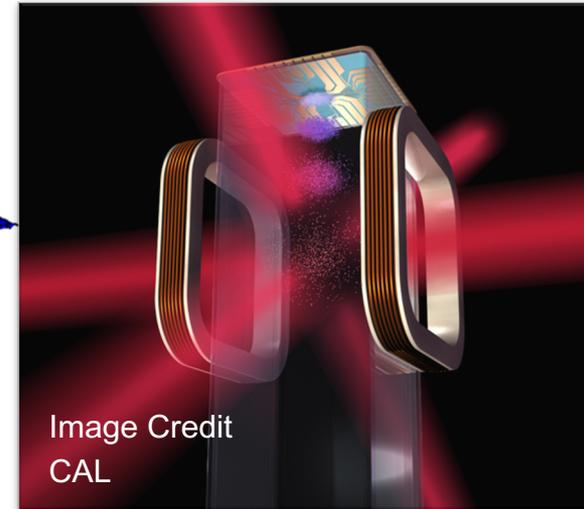


Image Credit
CAL

Fundamental Physics



CAL follow-on
under DLR
development in
partnership with
NASA

Image Credit
DLR

Oct 31, 2018

ASGSR 2018





NASA-DLR cooperation BECCAL – extreme physics with Bose-Einstein condensates



MAIUS



2017
First BEC
in Space



CAL



2018
First BEC
on ISS



BECCAL

2022
2nd generation
BEC experiments
on ISS



2007
First BEC in
microgravity

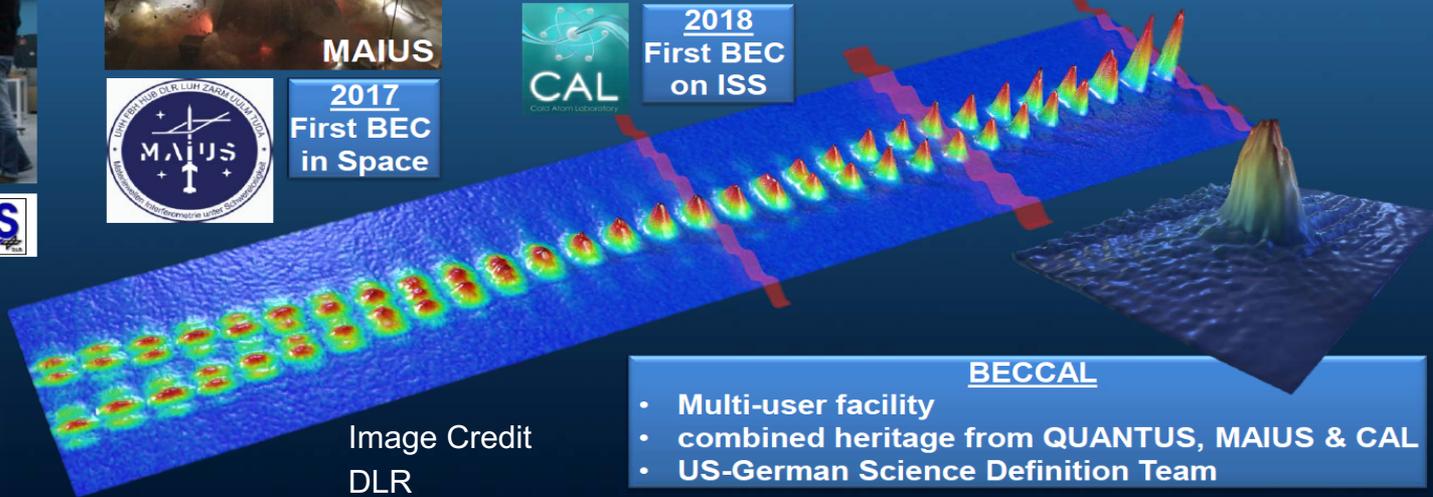
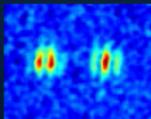


Image Credit
DLR

BECCAL

- Multi-user facility
- combined heritage from QUANTUS, MAIUS & CAL
- US-German Science Definition Team

Six Dedicated Research Areas investigating Quantum Physics in Microgravity

- Atom Interferometry
- Coherent Atom Optics
- Scalar Bose – Einstein Gases
- Spinor Bose – Einstein Gases and Gas Mixtures
- Strongly Interacting Gases and Molecules
- Quantum Information



DLR/NASA Implementing Arrangement



Fundamental Physics

- BECCAL is a DLR-NASA bilateral collaboration to develop a multi-user multi-purpose cold atom research facility aboard the ISS
- DLR will develop BECCAL and deliver to NASA for launch.
- DLR will operate BECCAL and provide raw data to German researchers and to JPL for use by US researchers.
- NASA will launch and install BECCAL in an ISS EXPRESS Rack.
- Each country will provide science definition team members to aid in BECCAL implementation.
- Each country will select and funds its own researchers.

IMPLEMENTING ARRANGEMENT
 BETWEEN
 THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
 AND
 THE GERMAN AEROSPACE CENTER
 FOR COOPERATION ON THE BOSE-EINSTEIN CONDENSATE COLD ATOM
 LABORATORY (BECCAL)

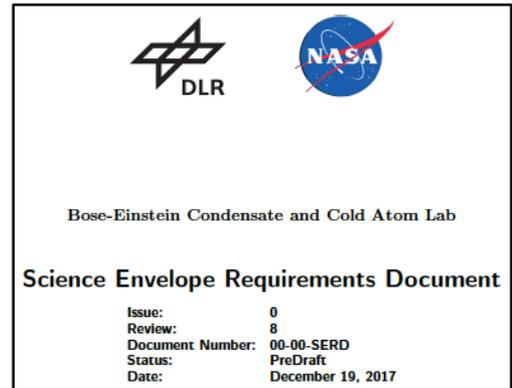
BECCAL Science Definition Team
Germany (DLR Funded)
Wolfgang Schleich, University of Ulm, Chair
Ernst Rasel, Leibnitz University, Hannover
Dennis Becker, Leibnitz University, Hannover
Markus Krutzik, Humboldt University, Berlin
U.S. (NASA Funded)
Dan Stamper-Kurn, UC Berkeley, Chair
Nathan Lundblad, Bates College
Holger Mueller, UC Berkeley
Benjamin Stuhl, Space Dynamics Lab

Providing a unique multi-user space facility for:

- Understanding quantum systems of atom optics, degenerate gases and their mixtures
- Testing the universality of free fall
- Studying methods and phenomena for Bose-Einstein condensation, atomic mixtures, delta-kick collimation and coherent manipulation by light pulses
- Studying Quantum phases (miscibility studies, spinor physics, etc.) in the vicinity of the transition thresholds
- Investigating few body and many body scaling and behaviors
- Exploring use of atom interferometers
- Exploring Satellite-based geodetic applications and Earth observations



- Create ultra-cold ensembles of different atomic species (87Rb, 85Rb, 41K, 39K, 40K).
- Maintain precise control of the position, center of mass velocity and expansion velocity of the ensemble.
- Control precisely the internal state of the atoms.
- Use light-pulse atom interferometry to conduct experiments concerning measurements of inertial forces.
- Study freely moving BECs propagating as coherent matter waves.
- Detect the atomic ensembles with absorption and fluorescence detection
- Use blue-detuned box potentials for condensate dynamics and interference



Control Electronics

Physics Package
Lasersystem

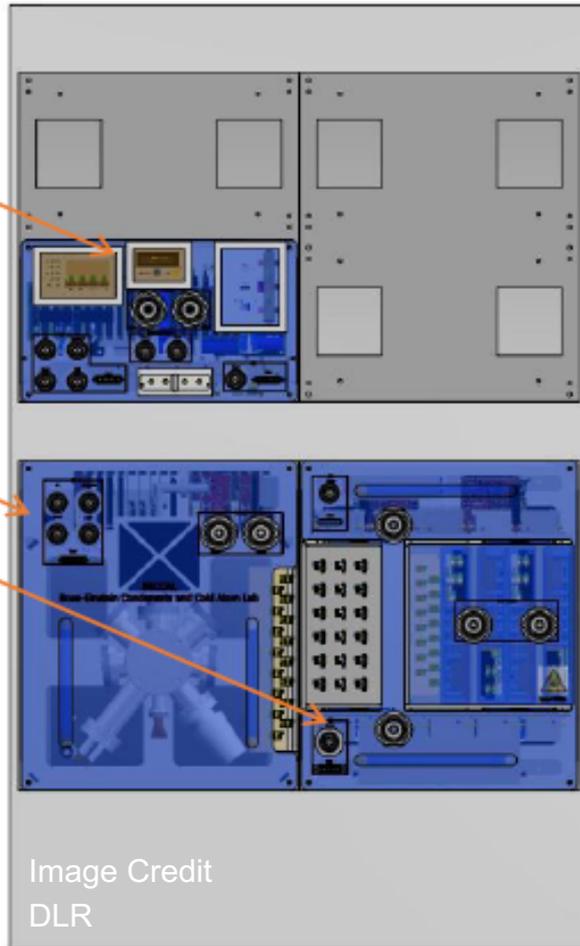
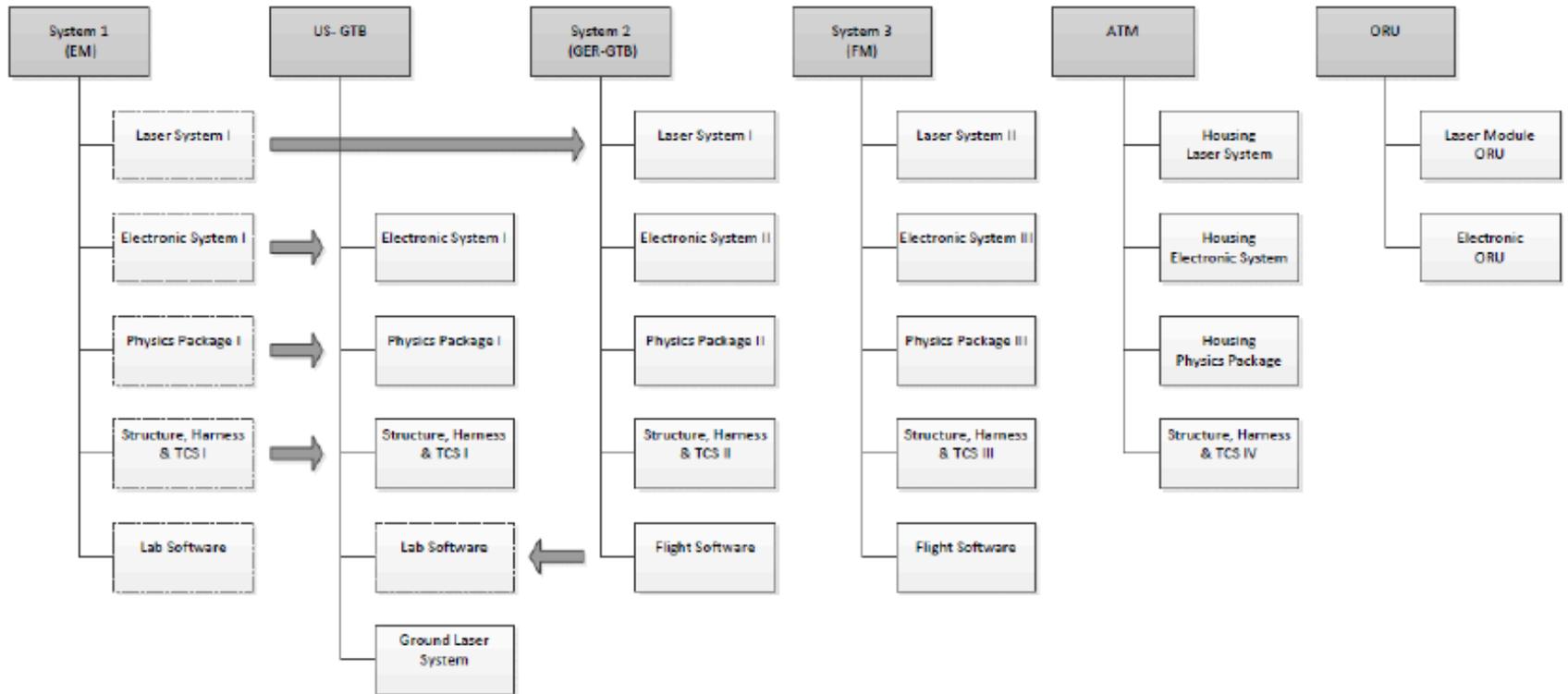


Image Credit
DLR

- Same 5-locker footprint as CAL
 - Physics Package Dual Locker
 - Laser System Dual Locker
 - Single Control Electronics Locker
- Modular Design
- Subsystems can be exchanged
 - Changeability of lifetime critical units via ORUs
 - Drawers for Subsystems and ORUs



Life Cycle: Minimum: 12 Months
 Foreseen: 36 Months

- BECCAL is a DLR/NASA collaboration to develop a multi-user multi-purpose cold atom research facility on the ISS.
- BECCAL has heritage from the DLR's on-going Quantus and Maius programs and from NASA's Cold Atom Laboratory on the ISS
- BECCAL has completed requirements definition activities and is in the preliminary design phase with PDR scheduled for Jan 2019.
- Launch is planned in 2022 followed by 2-3 years of operations
- U.S. Investigators are planned to be selected in 2021 through a NASA Research Announcements
- **Acknowledgements**
 - NASA Funding provided by the Space Life and Physical Science Research and Applications Division
 - German funding provided by DLR