The Colorado Center for Astrodynamics Research Facilities

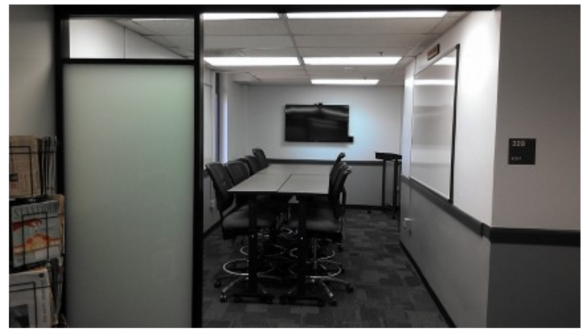
<u>Research group statistics</u>

CCAR is housed in the College of Engineering and Applied Sciences at the University of Colorado Boulder and has approximately 17,000 sq. feet of research space including offices, computing facilities and labs. The center was founded in 1985 and is currently home to 19 faculty, 15 Research Faculty, 1 Professional Exempt, 72 graduate students, and 17 undergraduate students.

Centralized Computing Facilities

<u>Centralized Computing Facilities</u>

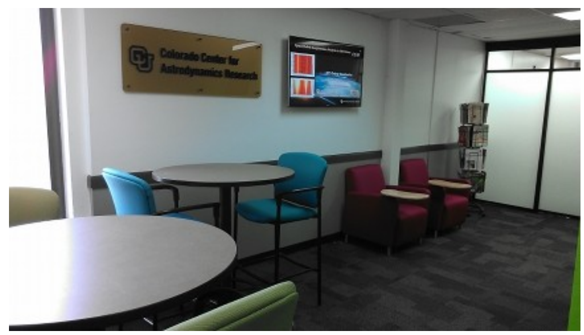
These facilities include a RedHat Enterprise Linux main server with a 30 Terabyte data storage RAID, a RedHat Enterprise Linux backup server with a 20 Terabyte data storage RAID, 52 RedHat Enterprise Linux workstations, 25 Windows 7 Enterprise workstations, 15 Mac OS X workstations, a centralized ITAR/EAR compliant RedHat Enterprise Linux processing workstation, and 6 specialized network attached storage arrays (NAS). All network connections within CCAR run on CAT5e or CAT6 cable at 1 Gbps network speeds.



The George H. Born Meeting Room

<u>The George H. Born Meeting Room</u>

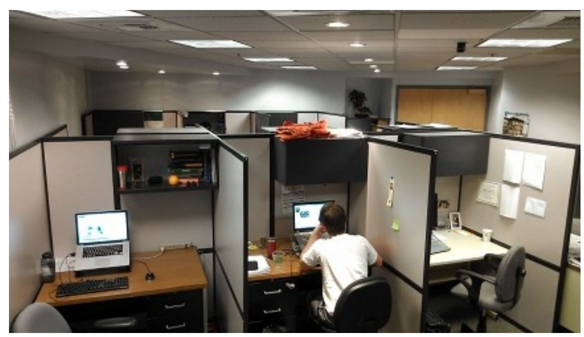
This 225 sq. ft. multimedia conference room is equipped to facilitate meetings and small lectures. Multi-user voice conferences are managed by a Polycom SoundStation 2 Expandable Conference Phone. Multi-user video conferences are managed by a 55″ Samsung F6300 Series Smart TV and an Intel NUC mini-PC running Windows 7 Enterprise. The video conferencing can be done using the most popular methods including Skype, GoToMeeting, & WebEx. Room Scheduling is handled by the CCAR Research Manager.



Reception and Lounge

<u>Reception and Lounge</u>

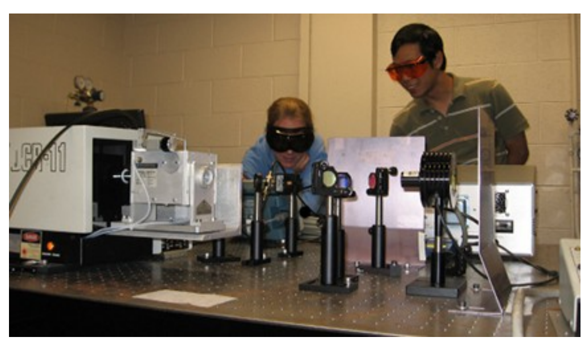
The reception area and lounge is a 300 sq. ft. area newly refinished with bistro style tables and chairs, signage, and a 47″ Samsung Smart TV displaying CCAR related pictures and videos. This area also houses the HP Color Laserjet 4700 printer, Konica-Minolta photocopier, and Faculty / Staff mailboxes.



Student Office Areas

<u>Student Office Areas</u>

Graduate students within CCAR are either assigned a desk in one of the research labs or in one of multiple areas maintained for student use. In these areas, computers are assigned on a case by case basis depending on the work and needs of the student. All students will have access to either the UCB Wireless network or the CCAR managed wired network for connectivity of personal laptops or CU owned computers.



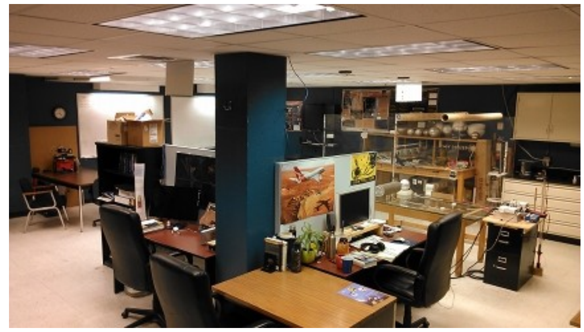
Active Remote Sensing Lab (ARSENL)

<u>Active Remote Sensing Lab (ARSENL)</u> – Dr. Thayer, Dr. Palo

The Active Remote Sensing Lab (ARSENL) consists of a 400 sq. ft. optics lab, a 600 sq. ft. RF electronics lab, and a 600 sq. ft. graduate student office space for 8 PhD students. The optics lab includes two full optical benches, optical/electronic diagnostic equipment, lasers and optical components to support research in designing, developing, and deploying lidar systems. The RF electronics lab includes electronic equipment, VHF radar transmitters and receivers, and data acquisition systems to support research in VHF radar system design, development and deployment. These active remote sensing techniques have led to field deployments in such remote locations as the Arctic and Antarctic. The lab supports research in geosciences involving water, atmosphere and space with a student workforce from PhD to undergraduates and even high school students.

Autonomous Vehicle Systems (AVS) Laboratory – Dr. Schaub

This 1000 sq. ft. laboratory space is used to investigate a variety of relative motion sensing and control problems. The AVS laboratory aims to develop hardware and software simulation environments to design, develop and test relative motion sensing technologies and control solutions. Originally developed with the support of Sandia National Laboratories, this lab uses an autonomous unmanned ground vehicle (UGV) to simulate the motion of aerospace vehicles and provide the sensor packages realistic relative motion. A particular research focus is the visual vehicle tracking concept. The AVS lab is also investigating how to simulate the charged relative translation and rotation of suspended vehicles using a standard atmospheric environment. The AVS lab utilizes Mac OS X based servers and workstations to carry out their research.



Autonomous Vehicle Systems (AVS) Laboratory

Celestial and Spacecraft Mechanics Lab (CSML) – Dr. Scheeres

CSML studies the fundamental mechanics of natural bodies, spacecraft, and debris within space environments throughout the solar system. The students and researchers that work at CSML have at their disposition three Mac Pro systems to carry out their research not including their individual laptops. As a whole, these systems can use 36 cores, allowing them to run up to 72 processes at any given time, with a combined storage capacity of 20TB. Given the always increasing computing needs of their research and their collaborators' (NASA, Ball Aerospace Inc., SwRI, Lockheed Martin Aerospace), these systems are accessible and fully utilized all year round. Additionally, this group has started experimental work on the dynamics of granular systems as this is related to surface dynamics and pod deployment on small NEOs.

Celestial and Spacecraft Mechanics Lab (CSML)

Commercial Spaceflight Operations (CSO) Lab – Dr. Parker, Dr. Born

This 650 sq. ft. Lab aims to support the ASEN 5519: Commercial Spaceflight Operations and Communications course. Students get hands on experience in performing spaceflight operations, mission management, and mission planning specifically in the rapidly developing context of the commercial spaceflight industry. The lab is home to 12 high end RedHat Enterprise Linux workstations that run various software packages including AGI's Satellite Tool Kit (STK), Braxton Technologies AcePremier Flight Dynamics System, & NASA Johnson Space Center's Copernicus Trajectory Design and Optimization System. The room is equipped with a Windows 7 Enterprise workstation that manages three 55" LG TV's and a projection system. This audio/visual system can be used for presentations or to highlight work done on individual workstations through a software setup consisting of VNC and remote desktop applications.

Commercial Spaceflight Operations (CSO) Lab

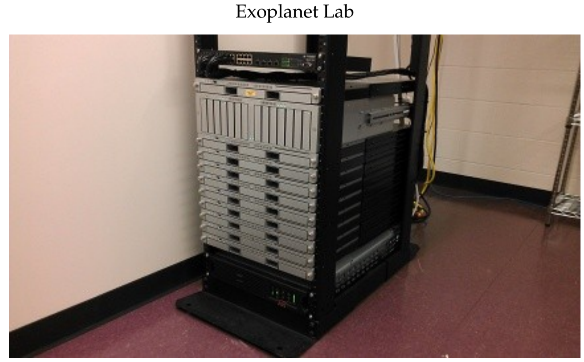
Exoplanet Lab – Dr. Cash

The Exoplanet Lab is a 15 meter long dark room that allows for the testing of diffractive optics. These optics include Starshade occulters that provide starlight suppression for the detection and characterization of Earth-like planets around other stars, along with diffractive optics to provide ultra-high resolution imaging from space. Additional work performed in this lab includes the development and testing of a vision-based sensor to enable the precision formation flying of suborbital vehicles to be used as starshade platforms.

Exoplanet Lab

Sea Level & GRACE Research Group – Dr. Nerem

The Sea Level & GRACE Research Group studies involve global and regional sea level measurements using satellite altimeters; processing of low-level data into climate-quality estimates of global mean sea level; research into sea level change and attribution to climate and interannual variations; analysis of GRACE data for geodesy. The group utilizes two Gentoo workstations: AMD Quad-Core, 16 GB RAM, shared 12TB RAID systems and a Mac based cluster with 10-nodes and a 7 TB RAID.



Sea Level & GRACE Research Group

GNSS/GPS Development & Analysis Laboratory – Dr. Axelrad, Dr. Akos

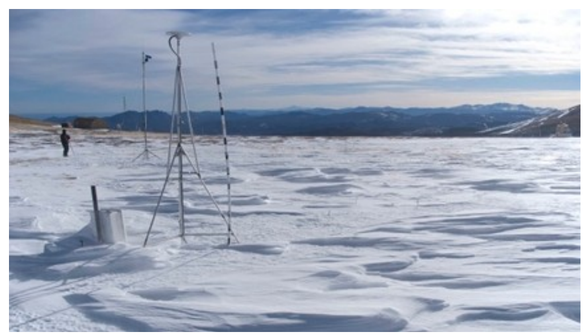
The GNSS/GPS Development & Analysis Laboratory works on GPS-based satellite orbit & attitude estimation, GPSRO & GPSR techniques for remotely observing the earth's environment, optical measurement modeling & estimation methods for space situational awareness, autonomous rendezvous & docking, and receiver design & implementation. The lab contains extensive radio (RF) test and measurement equipment, cabling, connectors, and antennas suitable for signals from baseband through S-band. Specifically the major test and measurement components within the lab include: a National Instruments full multi-constellation (GPS & GLONASS) simulator, a Spirent STR4500 full GPS constellation simulator, a 10 kHz-3.2 GHz Agilent signal generator, a 6.7 GHz National Instruments Vector Signal Analyzer/Generator with 50 MHz bandwidth record/playback capability, a variety of atomic-based frequency standards, a 9 kHz-3.6 GHz Rohde & Schwarz handheld network/spectrum analyzer, multiple GNSS single channels simulators, and various function generators, oscilloscopes, and power supplies. In addition, there are numerous RF discrete components such as filters (cavity, SAW, lumped element), low noise amplifiers, mixers, attenuators, RF adapters, and precision cables that can be used to construct custom RF front ends. The laboratory consists of number GNSS/GPS receivers from the smallest mass market devices to complete multiconstellation (GPS, GLONASS, Galileo, Beidou) multifrequency survey grade receivers. There is truth reference measurement system consisting of a GNSS/GPS receiver, a tactical-grade inertial measurement unit, and carrier phase differential real/post processing software package. It also can support rooftop experimental work using low loss cable drops from roof mounted GNSS/GPS antennas. Graduate students have offices in the grad lounge, Student Office areas, GPS lab, or the GNSS lab areas. Their work is generally performed on desktop computers connected to the CCAR network.

GNSS/GPS Development & Analysis Laboratory

GNSS/GPS Development & Analysis Laboratory

High-Precision GPS Applications – Dr. Larson

This group supports both high-precision GPS (and more generally GNSS) positioning applications and remote sensing research. For the latter, they have access to the GIPSY software developed at the Jet Propulsion Laboratory. The remote sensing research is primarily focused on soil moisture, snow depth, and vegetation water content measurements. They have approximately 10 GPS sites operating around the United States (Utah, Massachusetts, Colorado, Iowa, New Mexico, Oklahoma) that are used to validate the reflection products. They collaborate with hydrologists on the CU Boulder campus and with local scientists at UNAVCO, NOAA, and UCAR. They are also developing ways to monitor volcanic eruptions with GNSS sensors. The High-Precision GPS Applications group utilizes four Linux based workstations and a main server. They host both the PBO H2O water cycle research website as well as the GNSS Education and Outreach website.



High-Precision GPS Applications

Space Weather Lab – Dr. Knipp

The Space Weather Lab focuses on scientific inquiry into near-earth space. The work includes collaborations with NOAA National Geophysical Data Center with the aim to update, improve, and leverage various spacecraft datasets that provide information about energy deposition and dissipation at LEO altitudes. The primary focus is improving estimates of satellite drag. The analysis and archiving solution is Linux-based and leverages multiple mirrored workstations and redundant external and cloud-based storage to ensure dataset integrity and avoid disc-access bottlenecks. Our toolchain is primarily MATLAB and Python based, but includes IDL, Fortran and Javascript/jQuery.

Space Weather Lab

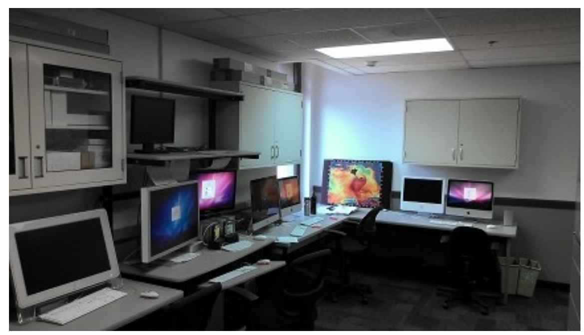
Imaging Lab – Dr. Emery
The projects worked on in this lab have to do with the analysis of a wide variety of satellite and UAV images. The facilities are primarily computational and data storage. All of the workstations run RedHat Enterprise Linux and many students use personal laptops as well. Data is stored both on local hard drives and on the CCAR localized storage RAID array.

Imaging Lab

Mission Design and Navigation Lab – Dr. Parker, Dr. Born
The MDNav Lab is focused on advancing the state of the art in spacecraft mission design and navigation, enabling new classes of missions and pushing the boundaries of solar system exploration. The group has special expertise in designing low-energy transfers, in optimizing low-thrust spirals and transfers, and in developing new ways to navigate satellites around the Earth and elsewhere. The group works with industry partners, notably Lockheed Martin Space Systems, the Jet Propulsion Laboratory, Johnson Space Center, Goddard Space Flight Center, Loctronix, Advanced Space, and others. Researchers have access to NASA software, including NASA/JPL's MONTE, MALTO, and LTool, NASA/JSC's Copernicus, and NASA/GSFC's GMAT and EMTG. The group is exploring new ways to parallelize mission design and navigation algorithms using CPUs and GPUs. The group is engaged in using software-defined radios to receive and harness HDTV transmissions from 10,000 broadcasting towers to be used as beacons for navigating spacecraft anywhere in the Earth-Moon system.

Mission Design and Navigation Lab

Near Real-Time and Historical Ocean Altimeter Data Archive – Dr. Leben
The Real-Time group manages an extensive database of near real-time and historical satellite altimeter data and analyses. The database can be accessed via direct FTP download or through an online web server that hosts a variety of data viewers to both view and overlay sea surface height maps on sea surface temperature and ocean color imagery provided by NOAA and NASA. A total of 164,270 images have been produced by users of the website. The core computing needs for this group are met by Mac OS X servers and numerous Mac workstations; backed by a BSD-based 32TB ZFS network attached storage pool. The software stack on these machines consists of MATLAB, Generic Mapping Tools, Python, JavaScript, other specialized tools.

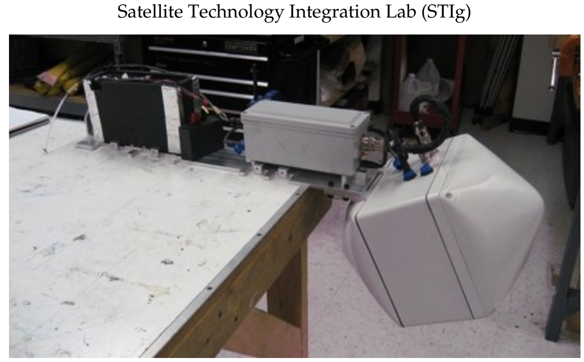


Near Real-Time and Historical Ocean Altimeter Data Archive

Satellite Technology Integration Lab (STIg) – Dr. Palo
The STIg is a 500 sq. ft. lab designed for subsystem testing and integration. All lab benches are equipped with ESD mats, chairs, continuous monitors and ionizers. Students are required to wear ESD coats while working in the lab. Lab equipment includes an ultrasonic cleaner, Helmholz cage, Agilent 480W solar array simulator 9kHz-3GHz Agilent spectrum analyzer and 9kHz-3.2GHz Rhode-Schwartz signal generator, plus multimeters, oscilloscopes, and power supplies. Research is done using four different workstations. There are two lab systems running Windows 7 Enterprise and then two ITAR compliant systems running RedHat Enterprise Linux and Windows 7 Enterprise for specialized work.

Satellite Technology Integration Lab (STIg)

Sea-Ice Remote Sensing Group – Dr. Tschudi
The Sea Ice Remote Sensing group is performing research which includes validation of sea ice products from the Visible Infrared Imaging Radiometer Suite (VIIRS) satellite and correction of the retrieval algorithms. The CULPIS-X instrument package, which contains a lidar to determine sea ice thickness, among other instruments is designed to fly on a US Coast Guard C-130A. A model to estimate sea ice drift speed and sea ice age is also maintained and run by this group.



Sea-Ice Remote Sensing Group