

ABOVE THE FOG

• BULLETIN OF THE SAN FRANCISCO AMATEUR ASTRONOMERS •

Vol. 63, No. 7 – July 2015

GENERAL MEETING

THE PRESIDIO . OBSERVATION POST . BUILDING 211

211 Lincoln Boulevard, San Francisco

7:00 pm Doors Open . 7:30 pm Announcements . 8:00 pm Speaker

Effective February 17, 2015: SFAA's General Meetings occur on the 3rd TUESDAY of each month (except January)

TUESDAY, JULY 21 - 7:30 P.M.

DR. STEVE CROFT, Ph.D.

UNIVERSITY OF CALIFORNIA, BERKELEY

DEPT. OF ASTRONOMY

**SNACKING, GORGING AND CANNIBALIZATION:
THE FEEDING HABITS OF BLACK HOLES**



A new generation of telescopes is coming online, with the capability to tell us about how black holes grow: by cannibalizing each other in stupendous mergers that shake the very fabric of space-time; by swallowing huge volumes of ten million degree gas; and by shredding and consuming stars that happen to pass too close. Observations of these processes are helping to transform our understanding of the growth of the enormous black holes that lurk at the heart of almost all galaxies.

Steve Croft studies black holes using a wide range of telescopes, including Hubble, the Shane Telescope at Lick Observatory, Keck, and most recently the Murchison Widefield Array in the remote Western Australian outback. He grew up in England, where he received a PhD in astrophysics from Oxford University in 2002, before moving to California to work as a postdoctoral

researcher at the Lawrence Livermore National Laboratory. Since 2007 Steve has been a researcher in the Astronomy Department at UC Berkeley, and is also involved in outreach, including for Berkeley SETI Research, and informal education, including the NASA NOVAS program.

SAN FRANCISCO AMATEUR ASTRONOMERS' NEW HOME



**NEW MEETING LOCATION
EFFECTIVE
FEBRUARY 2015**

THE PRESIDIO OBSERVATION POST - BUILDING 211

<http://www.presidio.gov/venues/Documents/Bldg%20211%20Floor%20Plan.pdf>

Driving Directions

<http://www.presidio.gov/venues/Pages/observation-post-at-the-presidio-driving-directions.aspx>

Public transportation information link

<http://www.presidio.gov/transportation/Pages/default.aspx>

UPCOMING LECTURES

August 18, 2015
Faride Khalaf



For some time, NASA has been looking beyond single-entity space transportation programs. Our future in space has never been more secure or as exciting. Over the last half century NASA was the sole organization to design our entire space program and to go ankle deep in the ocean that is our corner of the universe. With the knowledge and experience gained through risk and expenditure, the time has come to pay huge dividend to the investors. We are now for the first time in history, launching privately designed and built large scale space vehicles successfully. There are many corporations contending to provide commercial space transportation for NASA as well as for those private citizens with means and will to rise above the Earth's atmosphere for that rare glimpse at our home planet. NASA's Space Launch System (SLS) is the new protocol for the American Space Program. By sharing several decades' worth of essential and invaluable scientific data along with expertise and oversight, NASA is laying the foundation for a thriving aerospace industry and providing a great boost to our morale and economy. The SLS is an elaborate approach to lifting crew and cargo into the sky in a way that is safe, economical, and with greater options and flexibility. In this presentation you'll gain some insight into the future of space travel and understand why our traditional means of exploration are now history.

Faride Khalaf is a science writer who specializes in researching the history and events of the space age, and gives unique presentations in the Bay Area.

Faride studied mechanical engineering and astronomy. He began an aviation career as a skydiver, then became an Aircraft Mechanic Instructor. Faride worked for United Airlines as an Instructor and Fuel Systems Specialist, and taught aviation in Flight

School.

As a young child, he was fascinated with the night sky and asked his father why the Moon always appeared to follow him. He is an amateur astronomer with a telescope who loves to share his knowledge and enthusiasm. He is a certified telescope operator at the Chabot Space and Science Center, working with the 1883 8" and 20" telescopes. He speaks to Bay Area astronomy clubs on a variety of topics, and Faride has never stopped looking up.



September 15, 2015

Elisa Quintana, SETI Institute
Earth-Sized Planets in the Habitable Zones of Cool Stars

A primary goal of the Kepler mission is to determine the frequency of Earth-sized planets in the habitable zones of other stars. M dwarfs, stars that are smaller and cooler than the Sun, comprise more than 70% of the stars in our galaxy. Finding that Earth-sized planets around M dwarfs are common, therefore, has big implications for determining the frequency of other Earths.

In April 2014 we announced the discovery of Kepler-186f, the first definitive Earth-sized planet found to orbit in the habitable zone of a star other than our Sun. We will discuss our methods of combining ground-based observations with transit modeling to confirm this system, and will present our theoretical studies on the formation and habitability of this planet. We will also present updates on several promising multi-planet systems that have Earth-sized, and possibly sub-Earth-sized, candidates in the habitable zones of cool low-mass stars in the Kepler field-of-view.

Dr Elisa Quintana is a research scientist with the SETI Institute and NASA Ames Research Center where she works on the Kepler Mission to help search for and characterize extrasolar planets. Most recently, she led a team of astronomers to confirm Kepler-186f, the first Earth-sized planet found to orbit within the habitable zone of another star. Her research also includes creating computer models to study the formation, dynamical stability and habitability of rocky planets within and beyond our solar system.

Welcome to the SFAA – 2015 Yosemite Star Party at Glacier Point – July 24th and 25th



To sign up, just email Katie Gallinger at yosemite@sfaa-astronomy.org.

Sign up soon – It's filling up fast!

Remember, the trip is available to **MEMBERS ONLY**.

Since this is a Public Viewing Event that the SFAA attends as guests of the National Parks, all campers are expected to bring a telescope and be willing to host public viewing. The club aims to bring one telescope for every two SFAA members attending.

About the Trip:

The SFAA is provided with FREE admission to Yosemite National Park as well as FREE reserved, shared campgrounds at Bridalveil Group Campground.

The campsite is 8.5 miles away from Glacier Point.

We will host two public star parties at Glacier Point, on Friday and Saturday night. We have the public (about 200 – 300 people) from twilight for a few hours, and then the rest of the night (and all day) to ourselves; this is a mighty good deal, considering how some folks come 12,000 miles to see these rocks. The National Park Service limits astronomy clubs to a maximum of 30 SFAA campers. Please do not ask if your friends can come ...unless they are SFAA members and have telescopes.

Observing site at Glacier Point

The observing area is mostly open, with incredible views from about NNW to the east, around to due south. The horizon from south around to the west is partly blocked by tall trees. Still, there is a lot of open sky, and typically, the seeing and transparency are excellent. It has warm temperatures of 70 to 90 during the day, and cool to chilly 40's at night, due to the elevation of 7200 feet.

Star Party

One of the rangers does a sunset talk, and then delivers the crowd to us. Following that, a member of the club will give an evening talk, (want to volunteer?) The public will have white flashlights, and we need to be tolerant of that. We will have 3 club members with red brake light tape to politely cover the offending flashlights. Expect many questions from the public.

The Reward

By around 9:30 or so, we will have the place to ourselves, and can stay until dawn if you so choose. Scopes must be removed when we quit, then set up again on Saturday. Some of us may set up sun scopes during the afternoon, show Half Dome festooned with rock climbers, and invite people to come back again after sunset.

Gastronomic Astronomic

Early Saturday eve is the traditional potluck meal and is always tons of fun. Please provide enough food for ~ say 3 or 4 people. Salads, main courses, pu pu's, and desserts are all welcome. The question is: Who will have the best astronomical gastronomic theme of incredible edibles this year? Remember the Brown Dwarfs? Prizes will be awarded!

Please remember this repast takes time. It's better to start our own gastronomic party early so that there's no need to rush for set up Saturday evening on Glacier Point.

Check the [National Weather Service](http://www.nws.gov) for up-to-date weather info on Yosemite Park current weather and conditions.

See you at the campsite.
Katie & Paul



SAN FRANCISCO AMATEUR ASTRONOMERS

2015 STAR PARTY DATES Scott Miller

SEPTEMBER CHANGE OF DATE FOR MOUNT TAMALPAIS STAR PARTY

We were recently informed that The Mountain Theater on Mount Tamalpais has been double-booked for Saturday September 19. SFAA and the Friends of Mt. Tam had been planning to present a public astronomy program that night with Dr. Carolyn Porco talking about a decade of exploring Saturn with the Cassini spacecraft followed by a public star party in the Rock Springs parking area. But there will be a concert in the Mountain Theater September 19, so the schedule has been changed.

We will hold a public astronomy program on Saturday, September 12, with Dr. Porco's lecture starting at 8:00 pm, followed by telescope observing. There will be a new Moon that night, so this will be a great opportunity to show the public the Milky Way and other deep sky objects that show up best in a dark sky.

On Saturday, September 19, there will be an SFAA members night star party at Mt. Tam's East Peak. East Peak has a wide open horizon and a dramatic view of the entire bay area (which we hope will be covered by fog!).

Please make note of these changes. Telescope operators and other interested SFAA members are always needed at our star parties, both on Mt. Tam and in San Francisco. You can find the Mt. Tam public astronomy program schedule at <http://www.friendsofmonttam.org/astronomy/schedule>. SFAA members nights and City star parties are listed at <http://www.sfaa-astronomy.org/events/>.

Below is the schedule for 2015 San Francisco City Star Parties staffed by volunteers of the SFAA. Note that the Presidio, our new host for SFAA meetings during the Randall Museum renovation, is a favored Star Party location for 2015. Lands End, a traditional City Star Party location, and the popular Exploratorium museum, are the other Star Party sites.

Friday	July 24	Lands End, 8:00 PM
Tuesday	August 25	Presidio Parade Grounds, 7:30 PM
Thursday	September 24	The Exploratorium, 6:30 PM – MOVED TO SEPTEMBER 12
Thursday	October 22	Presidio Parade Grounds, 6:00 PM
Saturday	November 21	Lands End, 5:30 PM
Saturday	December 19	Presidio Parade Grounds, 5:30 PM



**FRIENDS OF
MT TAM**

Astronomy Nights on Mt. Tamalpais

Sign up for free Friends of Mt Tam [eMail Announcements](#)
Free and open to all (no signup)

2015 MT TAM ASTRONOMY PROGRAMS

Our 27th year on the mountain

<p>July 25 8:30pm</p>	<p>Dr. Phil Marshall, Kavli Institute, Project Scientist slac.stanford.edu/~pjm <i>“Weighing Galaxies”</i> We live in a galaxy of about a hundred billion stars, the Milky Way. As the sky over Mount Tam darkens, and the stars in the disk of our galactic home come into view, see how we are mapping out where the Dark Matter is, both in our local group of galaxies and further out in the depths of space. Galaxies are much heavier than they look – what could that mean for our understanding of how stars form, and what Dark Matter is?</p>
<p>Aug 22 8:30pm</p>	<p>Dr. Lynn Rothschild, NASA-AMES, Synthetic Biologist solarsystem.nasa.gov/people/profile.cfm?Code=Rothschild <i>“A Biological Perspective on the Meaning of Time”</i> Life is a phenomenon that integrates processes ranging from the near instantaneous reactions of photosynthesis to the more stately pace of evolution. How are these processes with radically different time scales creating and maintaining the diversity of life on earth? What are the clocks that nature uses to time them? And how is modern biology being used to alter the natural time scales?</p>
<p>Sept 12 8:00pm (Note Date Change)</p>	<p>Dr. Carolyn Porco, Space Science Institute, CICLOPS Director spacescience.org/about_ssi/staff/porco.html <i>“In the Land of Enchantment: A Decade Exploring Saturn”</i> A glistening spaceship, with seven lonely years and billions of miles behind it, glides into orbit around a softly-hued, ringed planet. A flying-saucer shaped machine descends through a hazy atmosphere and lands on the surface of an alien moon. These visions are not a dream but tell of the explorations of the Cassini spacecraft and its Huygens probe in 2004. Come along for the ride, and witness the sights and magic worked by these emissaries from Earth to the enchanting realm of Saturn.</p>
<p>Oct 17 7:30pm</p>	<p>Dr. Geoff Marcy, UC Berkeley, Professor of Astronomy astro.berkeley.edu/people/faculty/marcy.html <i>“Prospects and Hunting for Intelligent Life in the Universe”</i> Not one microbe has been found anywhere in the universe, except on Earth, nor have any intelligent civilizations been found. Is our Galaxy teeming with life, as suggested by science fiction, or might intelligent life be rare in the Milky Way Galaxy? New telescopes and techniques can answer these questions.</p>



SAN FRANCISCO

**AMATEUR ASTRONOMERS
EXPEDITION**

April 21, 2017

**TOTAL SOLAR ECLIPSE
Jackson Hole, Wyoming
(Teton Mountains)**

The San Francisco Amateur Astronomers is organizing an expedition to witness the August 21, 2017 Total Solar Eclipse. The eclipse will be visible across a broad swath of the USA, and club members will gather near Jackson Hole, Wyoming, to witness this spectacle high in the Teton Mountains. The trip is an opportunity for club members to gather in one place along the path of totality and journey together up the mountains for viewing of this spectacular astronomical phenomenon.

The club has arranged with a hotel in Teton Village, Wyoming, to enable advance bookings (2 years in advance!) with a special club rate of 10% discount. If you are a member of the SFAA and are interested in this, send an email to 2017eclipse@sfaa-astronomy.org and you'll be provided with additional details on the hotel and booking code. In the coming months the club will organize additional talks and events that will take place at the hotel on and before the date of totality. At this time, the most important thing is to book your hotel room so if you are at all considering this eclipse, get in touch and get your reservation in today. SFAA is not organizing air or ground transportation; that is left to each individual group or attendee.



If you have any other

questions, send to 2017eclipse@sfaa-astronomy.org.

BAY AREA ASTRONOMY EVENTS

Kenneth Lum

<http://tech.groups.yahoo.com/group/bayastro/?v=1&t=directory&ch=web&pub=groups&sec=dir&slk=94>

BAY AREA REGULARLY SCHEDULED EVENTS

**EVERY FRIDAY NIGHT
7:00 PM – 10:00 PM
excluding major holidays**

**The Telescope Makers'
Workshop**

**CHABOT SPACE AND
SCIENCE CENTER
10000 Skyline Boulevard
Oakland, CA 94619-2450**

THE TELESCOPE MAKERS' WORKSHOP is held every Friday night from 7pm - 10pm, excluding major holidays (e.g. Christmas Day and New Year's Day) that fall on Fridays. The Workshop is always closed on Memorial Day Weekend. Attendance every Friday night is not mandatory, and members work at their own pace. The Workshop meets at Chabot Space & Science Center, 10000 Skyline Blvd., Oakland.

Chabot's TMW is one of only a handful of regularly scheduled telescope making workshops in the U.S., and probably the world; it meets every Friday evening throughout the year, except Memorial Day weekend. It has been in operation since December of 1930, founded by Franklin B. Wright, and is currently run by Eastbay Astronomical Society member Rich Ozer, with help from other EAS members, Dave Barosso, Barry Leska, and others. The price of admission is FREE. All you have to do is show up, buy a mirror blank and a "tool" (typically around \$100 - \$200 depending on the size of the mirror) and start "pushin' glass!" We supply you with instruction, the various grits you'll need to first grind, and then polish and figure your mirror, and all the testing equipment needed. With a small bit of luck, you could wind up with a telescope that costs 1/3 or 1/4 the cost of a store-bought telescope, that is yet optically superior! It does take time - depending on how much time you put in on it, and other factors, it could take a few months or several months. But, it's a fun project, great for kids, and at the end you get a great telescope!

For more information call or email Richard Ozer at rozer@pacbell.net or phone (510) 406-1914.

**EVERY FRIDAY &
SATURDAY EVENING,
weather permitting
7:30 PM – 10:30 PM**

**CHABOT SPACE AND
SCIENCE CENTER
10000 Skyline Boulevard
Oakland CA 94619-2450
(510) 336-7300**

EXPLORE THE NIGHT SKIES AT THE CHABOT OBSERVATORIES

For more information: <http://www.chabotspace.org/>

Free Telescope Viewing

Regular hours are every Friday & Saturday evening, weather permitting: 7:30pm - 10:30pm

Come for spectacular night sky viewing the best kept secret in the Bay Area and see the magnificence of our telescopes in action!

Daytime Telescope Viewing On Saturday and Sunday afternoons come view the sun, moon, or Venus through Chabot's telescopes. Free with General Admission. (weather permitting)

12pm - 5pm: Observatories Open

**Sunset – 5:11 PM
(TWICE MONTHLY)**

**Inclement weather
(clouds, excessive wind
and showers) will cause
the event to be canceled
without notice.**

**SAN MATEO COUNTY
ASTRONOMICAL SOCIETY
STAR PARTY**

STAR PARTIES AT CRESTVIEW PARK, SAN CARLOS

Come out and bring the kids for a mind expanding look at the universe

The City of San Carlos Parks and Recreation Department and the San Mateo County Astronomical Society has open Star Parties twice a month. These events are held in Crestview Park, San Carlos California. Note that inclement weather (clouds, excessive wind and showers) will cause the event to be canceled without notice.

For more information call Bob Black, **(650)592-2166**, or send an email to SMCAS@live.com or call Ed Pieret at **(650)862-9602**.

Reasons to Attend

If you have kids interested in space or planets bring them here for a real life view of planets, nebula, star clusters and galaxies.

If you are thinking of buying a telescope or want help using a telescope you own, come here to talk with experienced users. If you think you might have an interest in astronomy come and talk to experienced amateur astronomers.

Cautions

Dress warmly and wear a hat.

Visitors should park on the street and walk into the park so your headlights don't affect the observer's dark adaptation.

Only park in the parking lot if you are arriving before dark and plan to stay until the end of the event.

You shouldn't need lights but if you feel you do, only bring a small flashlight with the lens covered using red cellophane or red balloon.

Please respect the telescopes and ask permission from the owner if you wish to touch.

Parents, please watch your children.

The park is residential, and adjacent to homes and backyards, please keep noise to a minimum.

Schedule Time

Astronomers arrive to set up at around sunset. Observing starts at about one hour after sunset and continues for two to three hours.

<p>EVERY CLEAR SATURDAY MORNING OBSERVATORY 10:00 AM – 12:00 PM</p> <p>FOOTHILL COMMUNITY COLLEGE 12345 Moody Road Los Altos Hills</p> <p>Cost: Free</p>	<p>Solar observing with a Hydrogen alpha solar telescope every clear Saturday morning. This allows spectacular views of solar prominences and unusual surface features on the Sun not otherwise visible with regular white light telescopes. Admission is free.</p> <p>Foothill Observatory is located on the campus of Foothill College in Los Altos Hills, CA. Take Highway 280 to the El Monte Rd. exit. The observatory is next to parking lot 4. Parking at the college requires visitor parking permits that are available from the machines in the parking lots for \$ 3.00.</p>
<p>EVERY CLEAR FRIDAY EVENING 9:00 PM – 11:00 PM</p> <p>FOOTHILL COMMUNITY COLLEGE OBSERVATORY 12345 Moody Road Los Altos Hills</p> <p>Cost: Free</p>	<p>Foothill Observatory is open for public viewing every clear Friday evening from 9:00 p.m. until 11:00 p.m. Visitors can view the wonders of the universe through the observatory's computer-controlled 16- inch Schmidt-Cassegrain telescope. Views of objects in our solar system may include craters and mountains on the moon, the moons and cloud-bands of Jupiter, the rings of Saturn, etc. Deep space objects including star clusters, nebulae, and distant galaxies also provide dramatic demonstrations of the vastness of the cosmos. The choice of targets for Any evening's viewing depends on the season and what objects are currently in the sky.</p> <p>The public viewing programs at Foothill are free of charge and are open to guests of all ages. Please note that the observatory is closed when the weather is cloudy. Also note that visitor parking permits are available from the machines in the parking lots for \$3.00.</p> <p>Come to Foothill Observatory and join us in the exploration of our Universe!</p> <p>Foothill Observatory is located on the campus of Foothill College in Los Altos Hills, CA. Take Highway 280 to the El Monte Rd exit. The observatory is next to parking lot 4. Parking at the college requires visitor parking permits that are available from the machines in the parking lots for \$3.00.</p>

NASA SCIENCE NEWS

Handprints on Hubble

June 26, 2015: It's funny, the things you notice hanging upside down in space.

Astronaut John Mace Grunsfeld remembers a quirky discovery back in 1999. He had just arrived at the Hubble Space Telescope and climbed out of the airlock of Space Shuttle Discovery to begin a servicing mission. Clinging to a handrail running down the side of Hubble's gleaming exterior, he ran his eyes over the blue planet 350 miles below and tried not to think too hard about the yawning starry expanse behind him. The astronaut, Hubble, and Discovery, connected together, raced around Earth at 17,000 mph.

That's when he noticed the handprints.

"The outside surface of Hubble is covered with them—scuff marks and other signs of handling by astronauts," says Grunsfeld.



A ScienceCast video explores the deeper meaning of superficial 'handprints' on Hubble.

Astronauts visited the orbiting telescope five times since it was launched in April 1990, conducting 23 spacewalks to repair and improve it. The "handprints" come from oil and silicon on the astronauts' gloves, which make an impression on Hubble's exterior foil. Initially invisible, these residues darken over time as they are exposed to solar ultraviolet radiation.

The prints Grunsfeld saw are more than chemical scuff marks, though.

"They are a symbol," he says, "of a unique human-robotic partnership."

Hubble's designers intended for astronauts to lay hands on Hubble. The telescope is festooned with knobs and handrails, hinged doors, and crawl spaces fit for astronauts to visit and tinker. This has allowed Hubble to do something no other spacecraft has done before—evolve.

When Hubble left Earth 25 years ago it was equipped with reel-to-reel data recorders, 1980s-era microprocessors, and some of the earliest digital cameras. Fast forward to the present: Almost every scientific instrument onboard the telescope has been replaced at least once. Hubble now has solid-state recording devices, upgraded computers, and astronomical detectors that far

outperform the older technology it originally took to space. Astronauts have also replaced the telescope's aging solar arrays, batteries, gyroscopes, some reaction wheels and fine guidance sensors. Keeping pace with technological advances on its home planet, Hubble is very much a creature of the 21st century.

Astronauts have done more than just upgrade Hubble. They have also saved it.

The first time was in 1993. When Hubble reached orbit, images revealed that the telescope's mirror was flawed. It suffered from a distortion called spherical aberration. Hubble could still take pictures of the cosmos but not with the sensitivity or resolution its designers envisioned.

"The first servicing mission in 1993 took care of that," says Grunsfeld. That December, seven astronauts flew to the telescope onboard Space Shuttle Endeavour. Over a period of 11 days, the crew conducted 5 spacewalks and used more than 100 specialized tools, many of which were invented specifically for the mission. They installed corrective optics, a new main camera, new solar arrays, and two new gyro packages.

Not everything went smoothly.

During the mission, spacewalkers Story Musgrave and Jeff Hoffman opened a pair of service doors to swap out gyros but could not get them closed again. The door bolts would not reset. Engineers on Earth speculated that when the doors were opened, a temperature change caused them to expand or contract.

"They ended up using a make-shift ratchet to squeeze those doors together," recalls Grunsfeld. "That was a very bad idea. It could have broken Hubble, but at the time, they didn't know that. Anyway, they squeezed the doors together using brute force."

Evidence of the wrestling match is evident today in a confusion of 'handprints' and scuff marks around the doors. The marks tell a silent story of ingenuity, risk, and triumph.

"Without that first servicing mission, Hubble would have been a nice telescope but not a great one," opines Grunsfeld. "We would not have measured the edge of the universe, validated black holes, or discovered dark energy. The fingerprints of astronauts are all over those advances."

Another difficult moment came in the late 1990s. Mission planners were growing nervous as Hubble's gyros unexpectedly started to fail—one in 1997, another in 1998, and a third in 1999. If one more gyro went offline, the telescope would not be able to point accurately.

The whole telescope was on the razor's edge of failure as Grunsfeld and six other astronauts readied themselves for Servicing Mission 3A. Indeed, just weeks before their Space Shuttle, Discovery, was scheduled to launch, a fourth gyro failed and Hubble science came to a screeching halt.

"We felt some urgency to get up there and fix the telescope," he recalls.

It would be Grunsfeld's first mission to Hubble, the first time he touched the telescope, and the first time he added his own prints to those of his predecessors. Discovery lifted off on Dec. 20, 1999. During the week-long mission, the crew installed new gyros, replaced a Fine Guidance Sensor (FGS) and swapped out the main computer. The new computer was 20 times faster and had six times the memory of the one it replaced.

"Coming out of that mission, we left the telescope in pretty good shape," he says. "We saved Hubble."

Little did he know, that rescue merely set the stage for a more thrilling one to come.

In 2000, engineers working on Hubble noticed a curious anomaly: The telescope's batteries were not charging as quickly as they should. It was a tiny effect, measured in units as small as micro-ohms, but over time it could add up to catastrophe: Hubble could "go dark" as early as 2003. With detective work that insiders still remember with awe 15 years later, engineers figured out the problem. There was a subtle ground fault in the telescope's Power Control Unit—or PCU.

The PCU is essentially a bank of relays that routes power from Hubble's solar arrays to its batteries and other systems. It is a very complicated device, and the only way to service it is to turn it off. Completely. No power to Hubble at all.

"This was kind of a big deal," says Grunsfeld. "If we didn't repair it, Hubble would die in about 3 years. On the other hand, if we tried to fix it, Hubble might die right away. Powering down Hubble had never been done before. Hundreds of relays would be switched to their powered-off state. A clock would be ticking because Hubble would get cold. There was a window of only a few hours to do the repairs because overnight Hubble would freeze, the optical bench would warp, and Hubble would no longer be functional."

NASA decided to go for it, and Grunsfeld started training for the most challenging mission of his career: Hubble Servicing Mission 3B. Flying Space Shuttle Columbia one last time before the disaster of 2003, the mission's crew would ultimately invent new tools, new training procedures, and new repair techniques to tackle the PCU problem. "We really upped our game," says Grunsfeld.

Around NASA, many experts worried about the PCU repair. Could it really be done? The astronauts themselves were worried. Sleepless in space, Grunsfeld and Rick Linnehan woke up early on March 2, 2002, and started prepping for their spacewalk more than two hours ahead of schedule. NASA prepared to cut power to the telescope as soon as they were ready to step outside.

"Keep in mind that as soon as power was off, we were on a ticking clock," says Grunsfeld. "There was a real sense of urgency, no question about it."

Immediately something went wrong: "Astronauts Mike Massimino and Jim Newman were preparing us to go outside," he says. "When Jim released me from the latches on the wall of the airlock, he noticed that my backpack was wet. A valve inside my spacesuit had failed and was leaking water. That's very bad. Had I gone outside, that water would have frozen, cracked an airline, and I could have been killed."

Suddenly the spacewalkers were behind schedule. Tick. Tock. Tick. Tock. Working quickly, astronauts in the airlock helped Grunsfeld out of his suit and assembled a new one from parts of other suits that fit him.

"In less than two hours—record time, by the way—we were able to get me back into a spacesuit. By the time we started the EVA, we were about two hours late. There was some mild panic on the ground because Hubble had been cooling off," he recalls.

The astronauts, however, were even cooler.

"You might think, 'Oh gosh, Rick and I must have been in a panic because we had already lost two hours of the day,'" says Grunsfeld, "But no. We went out the hatch as if everything was completely normal. We had that kind of focus from the training we had done. As soon as I was in the spacesuit again, I totally forgot that we had had all of those earlier problems. Rick and I went out and did it in 6.5 hours, exactly as we had trained."

The PCU was repaired, and the telescope powered up in good condition. Hubble was saved again.

NASA retired its Space Shuttle fleet in 2011, but not before one last visit to a telescope Grunsfeld now considered "an old friend."

Originally, plans called for Hubble to be serviced in February 2005, but the Columbia tragedy of 2003 changed everything. A trip to Hubble was deemed too risky, and for a while, it seemed that the telescope might never be serviced again.

"That would have spelled the end of Hubble," says Grunsfeld. "The telescope's batteries were 13 years old, and they were beginning to fail. Without replacements, the mission would have ended as early as 2007."

And it would have ended, except for the ensuing public outcry. Not only did astronomers wish to save Hubble but also millions of ordinary people did too. For more than two years, 2004-2006, school children wrote letters to the President, public hearings were held in Congress, and the "human connection" to Hubble became as clear as the glove-marks on its gleaming foil.

NASA reconsidered.

In May of 2009, Space Shuttle Atlantis blasted off for one last mission to Hubble. On the ground below, Space Shuttle Endeavour waited on the launch pad, ready to fly to the rescue if the crew of Atlantis got into trouble. This is how NASA managed the risk of flying the soon-to-be-retired spacecraft.

"By 2009 a ton of things were going wrong on Hubble," says Grunsfeld. "We did 5 EVAs to fix those things."

As usual, the astronauts had to invent new procedures and do the unprecedented—"like removing hundreds of tiny screws in bulky space suits," he recalls. They replaced batteries, swapped out all six gyros (again), installed a new Fine Guidance Sensor, repaired two of Hubble's scientific instruments and completely replaced two others. Mindful that astronauts might never visit Hubble again, the spacewalkers installed a soft-capture mechanism that would allow a future robotic spacecraft to grapple Hubble to ensure a safe conclusion to its operational lifespan.

For one last time, Grunsfeld saw the marks of the Hubble repair crews, the handprints of 16 spacewalkers: Story Musgrave, Jeff Hoffman, Kathryn Thornton, Thomas Akers, Mark Lee, Steve Smith, Greg Harbaugh, Joe Tanner, Mike Foale, Claude Nicollier, Rick Linnehan, James Newman, Mike Massimino, Andrew Feustel, Michael Good, and Grunsfeld himself.

"Leaving Hubble in 2009 was bittersweet," says Grunsfeld. "I was sad to see my old friend go. However, as a crew we were thrilled that we had accomplished all of our goals and a little more, sending Hubble off in the best shape ever."

Current estimates suggest that Hubble will continue doing great science until 2020 and possibly longer. All thanks to the human touch.

Credits:

Author: [Dr. Tony Phillips](#) | **Production editor:** [Dr. Tony Phillips](#) | **Credit:** [Science@NASA](#)



**San Francisco Amateur Astronomers
Application for New or Renewing Membership**

1. Memberships, with dues payment, are for one year running from standard renewal dates of 1 July to 30 June and 1 January to 31 December.
2. Submitting appropriate dues in April, May, June, July, August, September, membership will run to 30 June of the next year.
3. Submitting appropriate dues in October, November, December, membership will run to 31 December of the next year; submitting appropriate dues in January, February or March, membership will run to 31 December of the same year.
4. Renewals are maintained at the original membership date unless the renewal is made later than the original cutoff date (e.g. September or March as described in 3). In such cases the membership date is shifted to the next renewal date 30 June or 31 December.
5. New or renewal memberships sent in via USPS mail will have membership start date based on postmark date.

This application is for:

- New
 Renewing

Name: _____

Address: _____

Email: _____

Home Telephone (optional): _____

Cell Phone (optional): _____

Membership Type: Individual \$25.00 / Family \$30.00 / Student \$10.00 / Supporting \$75.00

Please mail to me a Mt. Tamalpais Parking Permit

To complete the membership process:

- A. Print and fill out this form
- B. Make check or money order payable to San Francisco Amateur Astronomers

C. Mail this form and payment to:

Treasurer, SFAA
PO Box 15097
San Francisco, CA 94115

New members will be entered onto the SFAA roster on the Night Sky Network (NSN) and will receive a verifying email from the NSN with username and password for the NSN. Renewing members will have their information updated but will not receive an email from the NSN. Both new and renewing members will receive a verifying email from the SFAA Treasurer upon completion of the membership process.