Communicating with Light: A New Dawn in the Information Age

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<u>*Presentation Goals:*</u>

1) *Give an appreciation for the vast scope of space communication applications*
2) *Lead an inspirational journey from where we've been to where we're going*
3) *Share the importance of technology to help get us there*

1) Introduction:

You and I are living in a very special time; the age of Solar System exploration. Our Solar System is a complex masterpiece of which we knew so little from our ground-based observations. But within the span of a single lifetime, NASA has sent spacecraft to every planet and several moons, our first eyes to set upon undiscovered lands.

Before we endeavored on this journey everything we knew of Pluto could have fit on a single file card, and now we downlink new data every day.

Human Tour:

We first televised pictures of our Earth from space in 1960.

Soon after we were together celebrating our first American orbits,

venturing outside to learn to space walk,

Pushing further to the moon, watching our Earth rise up over the moon's horizon.

We learned to coexist peacefully, and work together in space,

while also taking the time to revel in the simple joy of it all.

Look how far we have come, you and I, in our short history of space exploration, all within a single lifetime, all broadcast right to our homes…

2) Planet Tour:

We've journeyed to the very center of our system, to observe solar flares peeling off the sun in 3 dimensions.

We watch sunsets from the hills of Mars.

We monitor storms even larger than the Earth itself on Jupiter.

We gaze at the wandering rings of Saturn,

and ponder the vast unknown as Voyager 1 enters interstellar space after 35 years

3) Information:

By reaching for these new heights we are looking at data no one has seen before, taken from regions where no one has been before. Space offers the ultimate perspective. It is in our nature to explore, and the reward is that we learn more about ourselves and our surroundings.

Space communications offers us a conduit for bringing this valuable knowledge to the ground, and improves our everyday lives by providing us information to make better decisions about our planet. What we learn from space tells us more about our own world, and more importantly what it has in store for us in the future, so we may respond appropriately and share it with future generations.

4) SCaN:

If the last couple centuries focused on transporting energy and people, then this century is about moving information.

NASA currently communicates with over 100 spacecraft, placing increasing demands on legacy systems to keep up with the generated data.

The Space Communications and Navigation program, or SCaN, was formed to efficiently operate and evolve NASA's networked systems around the world for future Science and Exploration needs.

Certain missions require maximum connectivity with the Earth, so they communicate through a series of relay satellites circling the planet called the Tracking and Data Relay Satellite System, or TDRSS.

The largest customer for TDRSS is the International Space Station, where it is imperative to remain in contact with the astronauts and cosmonauts on board.

Interplanetary missions utilize SCaN's deep space network, or DSN. The DSN is a series of 3 ground terminals featuring the very largest of NASA antennas to reach far out into the solar system and beyond.

The navigational assistance provided by the DSN is so good we can place multiple spacecraft within proximity of each other during critical events, such as the Mars Science Laboratory Entry Descent and Landing. This event was observed by orbiting spacecraft, and transmitted back to Earth once the rover was safely on the surface. The orbiters continue to monitor the progress of the rover from high above, and together they form a communications network at Mars to work signals back to Earth.

Despite these advances, we are still leaving up to 95% of the data on our spacecraft, never to be recovered. Imaging and remote sensing technologies have far outpaced our ability to transmit their data back to earth, and especially from deep space. The most important reason we explore, information, is being limited by the communication technologies we use today. Our Universe is dynamic, and one has to wonder, what are we leaving on the table? What is the data in between the images? What all are we missing? How can we get there?

5) Optical:

Here on earth fiber optic technologies have enabled significantly faster data rates, and although it is not practical to run optical fibers all the way back from Mars, free space lasers can be used to achieve similar performance in space. The current renaissance of laser communication technologies can offer data rates 100 times faster at a fraction of the mass when compared with existing radio frequency communication systems, by encoding information onto a laser beam and transmitting back to Earth with a small telescope instead of an antenna. An early proof was the Lunar Laser Communication Demonstration, where a spacecraft orbiting the moon acquired a laser beacon from Earth and able to transmit at a rate of 6 times faster at 25% less mass than the RF system. Through the laser we sent video and an image of the Mona Lisa to the moon, and returned them back to the Earth, error free. At these rates over 30 channels of high definition video may be streamed simultaneously, and the current laser communication technologies under development promise an even further increase in performance.

6) iROC:

The next step is to evolve laser communications into an operational system for missions to use, and the Glenn Research Center's Integrated Radio and Optical Communications project, or iROC, aims to do exactly that. iROC combines the robustness of the existing radio frequency network with the speed offered by developing laser technologies into a single package to break through today's science data bottleneck in communicating with Earth. iROC's combination of operational and emergent technologies is analogous to the American combined Steam and Sail ships when boilers were first being developed in the 1800s.

At the front of the iROC system is a combination optical telescope and radio frequency antenna called a Teletenna. You are looking at a prototype teletenna for laboratory testing, which aligns the laser beam down the center of the RF pattern. The flight model for the Teletenna is manufactured out of very lightweight materials including a gold plated mesh from Northrop Grumman Astro for the RF signal and composite optics developed by Vanguard Space Technologies and NASA GRC for the laser beam. The full size of the Teletenna spans 3 meters in diameter, and attaches to a compact lightweight vibration isolation platform for stabilization being manufactured by Applied Technology Associates through a Small Business Innovation Research (SBIR) program.

As anyone who has given a presentation with a laser pointer knows, aiming the beam very accurately can be challenging, and this is especially true for space laser communications. Over large distances the communications beam may spread to about the size of Texas, which may seem large, but from Mars this is essentially trying to aim a point onto a point. Precise pointing of the Teletenna requires new technology development, and NASA GRC is working with the Optical Physics Corporation to improve the accuracy of small lightweight star trackers to accomplish this challenge. The basic concepts of star tracking has been used since the beginning of maritime navigation, and here is adapted with modern optics and electronics for increased fidelity in space. An iROC equipped craft first acquires images of star fields using improved hardware, and then fuses them together to form patterns. The resulting patterns are compared with an onboard star catalog database to determine exactly where the spacecraft is pointed, and more importantly where the communications beam needs to be projected to intercept Earth. Precise pointing actuation of the communications payload is accomplished through a mechanical system developed by Balcones Technology through an SBIR, and small fine pointing mirrors.

Spacecraft data is placed onto the laser beam in a process called modulation, which is performed by iROC's Software Defined Radio, or SDR. The SDR has heritage from GRC's SCaN Testbed project, which is currently flying on the ISS. The SDR team is developing the optical functionality to support varying mission parameters to prototype a radio capable of software reconfiguration, based on a Harris Corporation platform, to evolve during the mission as new technology and requirements are developed. The output of the optical SDR places the data onto the laser beam, which transmits the signal across the laboratory using small telescopes to be evaluated for beam quality and data integrity.

iROC is helping to transition NASA from having a series of individual point-to-point communication links to realizing a Solar System Internet through the advancement of network protocols tolerant to the delay, disruption and disconnections inherent in space communications. These protocols are prototyped in the laboratory and evaluated to optimize parameters such as efficiency, reliability, security, quality of service and interoperability with our space-faring partners. Data traffic is generated by an instrumented robot in the laboratory, and sent across the prototype iROC communications system using orbital predicted connections to evaluate the delay tolerant networking protocol's ability to successfully route the information to the Earth ground terminals in an efficient manner. A version of DTN is now deployed on the ISS, and will continue to be utilized for future missions.

Finale:

Over 93% of the nation witnessed Neil Armstrong place our first steps upon the moon, as downlinked through the Australian tracking station. And then we left.

Whether you were in the control room back then pioneering through both tragedy and triumph, or working a console within space operations today, or watching the display at home waiting for the signal - the experience is the same. Nothing changes. Watching, waiting for the telemetry to arrive, to tell us the system is OK, allowing us once more to experience the unknown.

It is our charge to put into place unbridled communications technologies which will enable all of us to share in the first human presence on Mars. Tune in and join us on our next journey through the solar system, we have an opportunity to learn so much more, to continue to improve our lives here on Earth, and lay the foundation for the next generation of discoveries.

7) Acknowledgments:

I would like to recognize the NASA communications teams, industrial and academic partners who strive to make this all possible, and emphasize that it takes all kinds of people to pull it off from engineers, scientists, mathematicians, technicians, operators, resource analysts, managers, facilities, safety, legal…and of course outreach to bring these very messages to you. Thank you all.