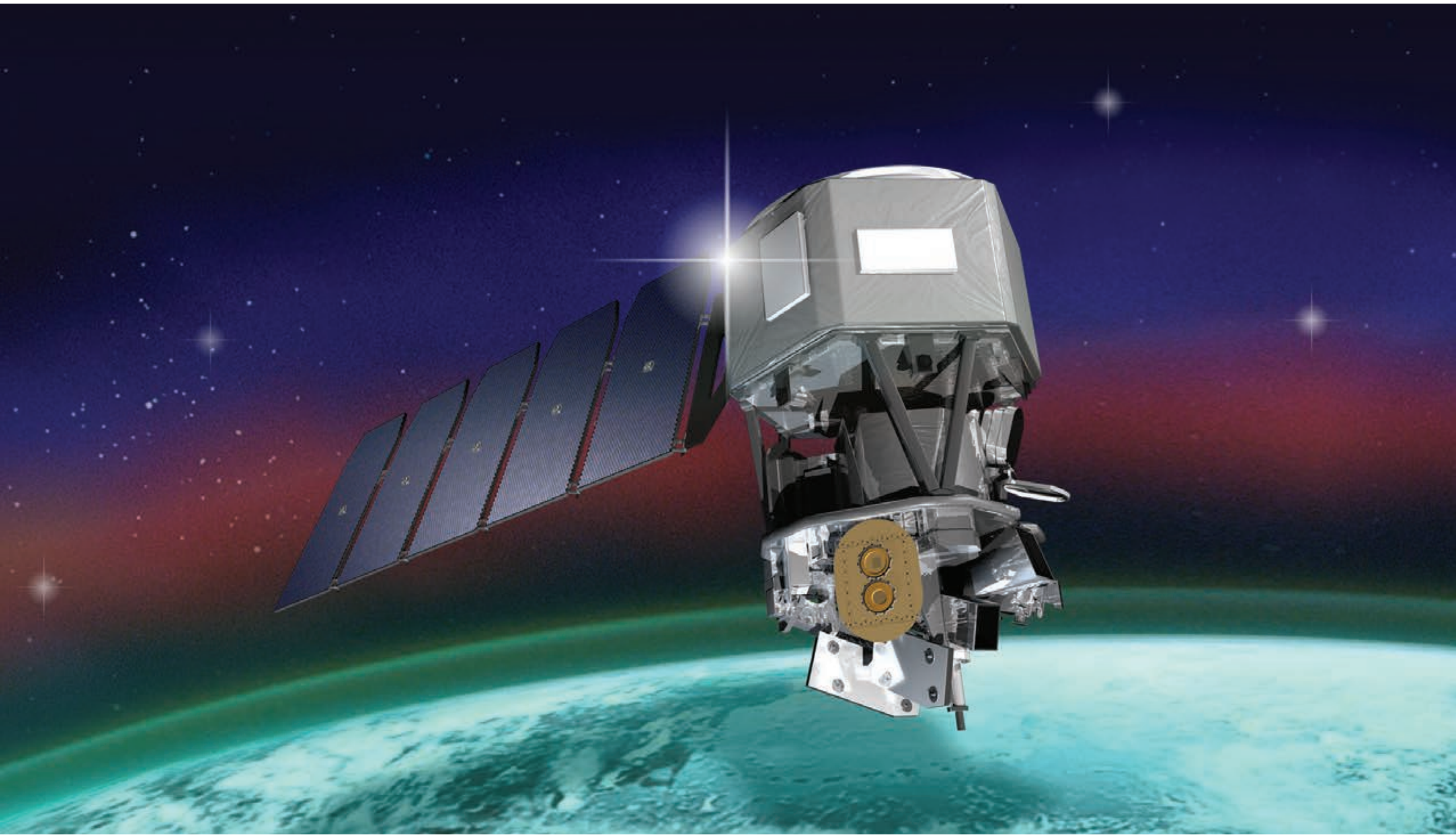
National Aeronautics and
Space Administration

ICON

Ionospheric Connection Explorer



Exploring the Ionosphere,
Earth's Interface to Space

Press Kit • November 2018

www.nasa.gov

ICON

Ionospheric Connection Explorer

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For more information about ICON, visit:
www.nasa.gov/icon

Mission Overview

The Ionospheric Connection Explorer, or ICON, will study the frontier of space: the dynamic region high in our atmosphere where terrestrial weather from below meets space weather from above. Here, the tenuous gases that fill Earth's upper atmosphere—a mix of neutral and charged particles—are anything but quiet, as vast, high-altitude winds redistribute them throughout the edge of space. These winds can change on a wide variety of time-scales due to factors including Earth's seasons, the day's heating and cooling, and incoming bursts of radiation from the Sun.

This region of space, called the ionosphere, and its constant changes have practical repercussions, given our ever-increasing reliance on technology: This is the area through which radio communications and GPS signals travel. Variations here can result in distortions or even complete disruption of such signals. In order to understand this complicated region of near-Earth space, NASA has developed the ICON mission. Understanding what drives variability in the ionosphere requires a careful look at a complex system driven both by terrestrial and space weather.

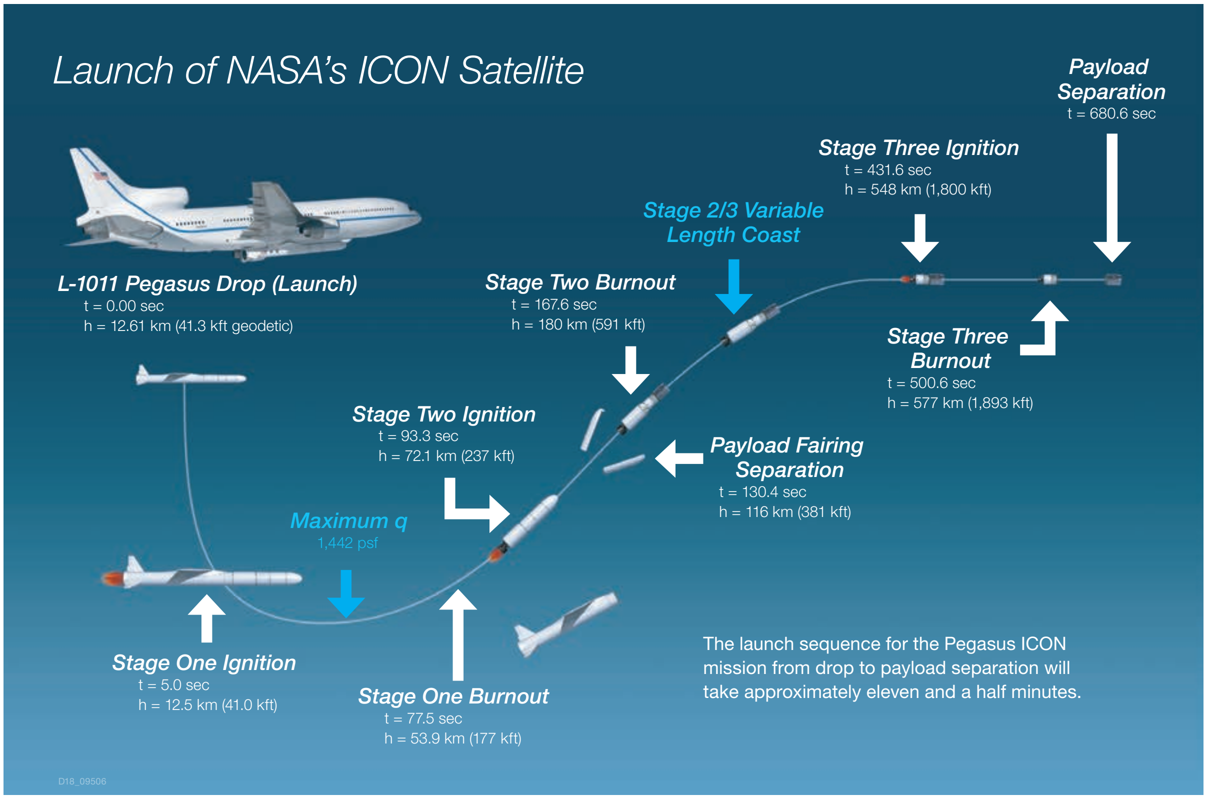
ICON is a NASA Explorer mission. The Explorers Program Office at NASA's Goddard Space Flight Center in Greenbelt, Maryland, provides management of the multiple scientific exploration missions within this program. Explorer-class missions are principal investigator-led, relatively moderate cost, small- to medium-sized missions that are capable of being built, tested and launched in a short time interval compared to large observatories.

ICON will help determine the physics of our space environment and pave the way for mitigating its effects on our technology, communications systems and society. ICON will launch no earlier than November 7, 2018 EST.

ICON Mission Quick Facts

Launch Date:	November 7, 2018 EST
Launch Site:	Cape Canaveral Air Force Station, Florida
Launch Vehicle:	Northrop Grumman Pegasus XL rocket is carried aloft by the Stargazer L-1011 aircraft to approximately 40,000 feet over the open ocean, where it is released and free-falls five seconds before igniting its first-stage rocket motor. Pegasus XL dimensions: - Length: 57.4 feet - Diameter: 4.2 meters - Mass: 52,910 lbs (24,000 kg)
Pegasus Drop:	Targeted for 3:05 a.m. EST. The drop window is daily, 3:00-4:30 a.m. EST.
Spacecraft Deploy:	Targeted for 3:16 a.m. EST.
Orbit:	Low-Earth, circular orbit at 27-degree inclination to the equator, at an altitude of 360 miles (575 km)
Orbital Period:	97 minutes for each orbit around Earth
Mission Duration:	Baseline two-year science mission
Mission Operations:	The Space Sciences Laboratory at the University of California, Berkeley, performs ground commanding, flight operations and data telemetry.
Science Operations:	The University of California, Berkeley, performs science operations and provides data processing and archiving.
Ground Data Passes:	The Space Sciences Laboratory at the University of California, Berkeley, provides the primary ground station, the 11-meter Berkeley Ground Station dish. Other ground stations are located in Singapore, Chile, Hawaii, and the continental United States.

Northrop Grumman Pegasus XL Rocket Launch Profile



Credit: Northrop Grumman

ICON Observatory Quick Facts

Mass: Total observatory mass is 634 lbs (288 kg). Science payload is 286 lbs (130 kg). There is no onboard fuel.

Power: Power consumption ranges between 209-265 Watts when in science mode.

Dimensions: The observatory is 76 inches tall with a 42-inch diameter, about the size of a large refrigerator.

Solar Arrays: The solar array deployed is approximately 100 inches long and 33 inches wide, providing a total surface area of 3,300 square inches (22.9 SF)—just larger than a door.

Maximum Downlink Rate: The science S-band data rate is 4 Mbps, delivered over 5-6 daily contacts. Maximum downlink time per day is 40 minutes. The expected volume of data generated by the observatory is approximately 1 gigabit per day.

The second and third stages of the Northrop Grumman Pegasus XL rocket are off-loaded from a transport vehicle at Building 1555 at Vandenberg Air Force Base in California in May 2017 in preparation for ICON's launch.

Credit: NASA/Randy Beaudoin

ICON Science

NASA's Ionospheric Connection Explorer, or ICON, investigates the connections between the neutral atmosphere—which extends from here, near Earth's surface to far above us, at the edge of space—and the ionosphere, the layer of the atmosphere ionized by solar radiation.

The ionosphere is home to many low-Earth orbiting satellites, including the International Space Station. It also acts as a conduit for many of our communications signals, such as radio waves and the signals that make GPS systems work. Particles in the ionosphere carry electrical charges that can disrupt communications signals, induce electrical charge in low-Earth orbiting satellites, and, in extreme cases, spark power outages on the ground. Unpredicted changes in the ionosphere, such as ripples and bubbles of dense plasma, can have significant impacts on our technology and communication systems.

Positioned on the edge of space and intermingled with the neutral atmosphere, the ionosphere's response to conditions on Earth and in space is difficult to pin down. Pressure differences created by weather near Earth's surface can propagate into the very highest reaches of the upper atmosphere and influence the winds in this region. The exact role these winds—and by extension, terrestrial weather—play in shaping the ionosphere remains an outstanding question, and one that scientists hope ICON will answer.

ICON explores these connections between the neutral atmosphere and the electrically charged ionosphere with four different types of instruments. Three of these four types rely on one of the ionosphere's more spectacular phenomena: airglow. Airglow is created by a similar process that creates the aurora: Gas is excited and emits light. While auroras are typically confined to extreme northern and southern latitudes, airglow occurs constantly across the globe, though it can be much fainter. ICON's instruments are designed to capture even the faintest glow to build up a picture of the ionosphere's density, composition and structure. ICON's three airglow instruments view airglow from miles away to measure the temperature, velocity, and composition of Earth's atmospheric gases.

ICON's fourth instrument type provides direct measurements of the ionosphere around it. This in situ instrument characterizes the charged gas immediately surrounding the spacecraft.

Ionosphere and Space Weather Basics

What is the ionosphere?

The ionosphere is the part of Earth's upper atmosphere where particles have been ionized, meaning they have been split apart into a sea of positively charged ions and negatively charged electrons called plasma. The plasma of the ionosphere is commingled with the neutral upper atmosphere, called the thermosphere. Because much of the upper atmosphere is above the ozone layer, it is exposed to the full brunt of the Sun's radiation, which ionizes some particles, creating the ionosphere. This means that the ionosphere extends farther on Earth's day side than on the night side.

What is space weather, and how is it related to the ionosphere?

Space weather refers to the ever-changing conditions in space that can influence technology and other systems on and orbiting Earth. Space weather is often triggered by changes on the Sun, which releases a constant outflow of magnetized material called the solar wind, along with less frequent but more intense bursts of solar material, called coronal mass ejections. The magnetic fields embedded in this solar material can temporarily disrupt Earth's natural magnetic field, shifting electric and magnetic fields in near-Earth space.

The electrically charged gas of the ionosphere, called plasma, reacts uniquely to these changing electric and magnetic fields. The ionosphere is where space weather manifests, creating conditions that can affect Earth-based technology—such as electric currents that can cause electrical charging of satellites, changing density that can affect satellite orbits, and shifting magnetic fields that can induce current in power systems, causing strain or even blackouts.

How does Earth's weather influence the ionosphere?

The ionosphere is shaped both by space weather from above and Earth's weather from below. Pockets of high or low pressure are generated near Earth's surface by weather like hurricanes or thunderstorms, or even phenomena as simple as a steady wind over a mountain range. These pressure differences can propagate into the very highest reaches of the upper atmosphere and influence the winds in this region. The exact role that these high-altitude winds play in shaping the ionosphere is an outstanding question, and one that scientists hope ICON will help answer.

Why do changes in the ionosphere matter?

Many low-Earth orbiting satellites, including the International Space Station, fly through the ionosphere and can be affected by its changing electric and magnetic fields. The ionosphere also acts as a conduit for many of our communications signals, such as radio waves and the signals that make GPS systems work. Unpredicted changes in the ionosphere, like ripples and bubbles of dense plasma, can have significant impacts on these signals and disrupt communications and navigation.

ICON Mission Operations

Mission Orbit

ICON will fly in an orbit around Earth at a 27-degree inclination and at an altitude of some 360 miles (575 km). This places it in a position to observe the ionosphere around the equator. ICON will aim its instruments for a view of what's happening at the lowest boundary of space at about 55 miles up to 360 miles above the surface. This rapid orbit circles Earth in 97 minutes while precessing quickly around the equator, allowing ICON to sample a wide range of latitude, longitude and local times.

ICON's orbit is also designed to create a few points during each orbit where the remote sensing instruments look straight down Earth's magnetic field, so that the in situ plasma measurements are sometimes directly magnetically connected to the remote airglow measurements, even though they are hundreds of miles apart.

Data Path and Rate

The Space Sciences Laboratory at the University of California, Berkeley, is responsible for mission operations and data processing and archiving. The Space Sciences Laboratory will provide the primary ground station. Other ground stations in Singapore, Hawaii, Chile, and the continental United States—as well as NASA's space-based Tracking and Data Relay Satellite System, or TDRSS—provide plenty of opportunities to communicate with ICON.

The science S-band data rate is 4 Mbps, delivered over 5-6 downlink passes. Maximum downlink time per day totals 40 minutes. The expected volume of data generated by the observatory is approximately 1 gigabit per day, or about 1 gigabyte per week.

ICON Instruments

The ICON mission includes four different types of instruments to study the neutral upper atmosphere and ionosphere both in situ and remotely.

Michelson Interferometer for Global High-resolution Thermospheric Imaging (MIGHTI)

The Michelson Interferometer for Global High-resolution Thermospheric Imaging instrument observes the temperature and speed of particles in the neutral atmosphere. These winds and temperature fluctuations are driven by weather patterns closer to Earth's surface. In turn, the neutral winds drive the motions of the charged particles in space. MIGHTI is built by the Naval Research Laboratory in Washington, DC.

Far Ultra-Violet instrument (FUV)

The Far Ultra-Violet instrument captures images of the upper atmosphere and ionosphere in wavelengths of far ultraviolet light. At night, FUV measures the density of the ionosphere, tracking how it responds to weather in the lower atmosphere. During the day, FUV measures changes in the chemical composition of the upper atmosphere—the source for the charged gases found higher up in space. FUV is built by the University of California, Berkeley.

Extreme Ultra-Violet instrument (EUV)

The Extreme Ultra-Violet instrument captures images of oxygen glowing in the upper atmosphere, in order to measure the height and density of the daytime ionosphere. This helps scientists track the response of the space environment to weather in the lower atmosphere. EUV is built by the University of California, Berkeley.

Ion Velocity Meter (IVM)

The Ion Velocity Meter measures the speed of charged particles, which move in response to the push of high-altitude winds and the electric fields they generate. The IVM is built by the University of Texas at Dallas.

ICON Mission Management

ICON is a principal investigator-led, NASA Explorers Program mission. Primary management responsibilities are as follows:

NASA's Goddard Space Flight Center (Greenbelt, Md.):
- Explorers Program management
- Project oversight

University of California, Berkeley:
- Principal investigation institution
- Mission operations
- Management and technical engineering support for instrument and spacecraft development teams
- Science communication
- Flight software
- Payload electronics
- Data archiving
- FUV and EUV instrument design, build and management

Space Dynamics Laboratory/Utah State University Research Foundation (North Logan, Utah):
- MIGHTI camera design, build and delivery to NRL
- FUV camera design, build and delivery to UCB
- Payload integration and testing

University of Texas at Dallas:
- IVM instrument design, build and management

NAVAL Research Laboratory (Washington, D.C.):
- MIGHTI instrument design, build and management

NASA's Launch Services Program

NASA turns to the engineers and analysts in its Launch Services Program, or LSP, to send robotic spacecraft on their way for some of the most exciting and notable missions in the agency's history.

The program is based at NASA's Kennedy Space Center in Florida and boasts a roster of engineers and technicians who specialize in all aspects of rocketry and spacecraft integration. LSP selects the appropriate launcher for a mission's spacecraft, in this case the Northrop Grumman Pegasus XL for ICON. Sometimes this selection process takes place years before the first launch opportunity. The program then provides oversight as the designs of the rocket and mission are integrated with each other.

As liftoff nears, teams oversee the launch vehicle's engineering and manufacture and its integration with the spacecraft. LSP conducts the countdowns for NASA's scientific missions and provides additional quality assurance along with other controls to ensure a successful mission.

Working with commercial rocket builders, planners have a number of rocket models to choose from, ranging from the small, air-launched Northrop Grumman Pegasus used for ICON, to the workhorse Delta II rocket from United Launch Alliance, to the powerhouse Atlas V, also from ULA. The catalog is growing with the addition of the SpaceX, Falcon 9 and Northrop Grumman Antares rockets.

LSP moved its operations to Kennedy in 1998, becoming the first program based at the nation's premiere launch site. The 14 years since then have seen orbiters, landers and rovers to Mars, huge observation spacecraft to Jupiter and the New Horizons mission launched to Pluto and the Kuiper Belt, two astronomical locations that have never been seen up-close before.

Because some spacecraft need to fly in a different kind of orbit, LSP operates several launch centers around the world. Cape Canaveral Air Force Station in Florida—where ICON is launching—is adjacent to Kennedy Space Center and hosts launches to place spacecraft in orbits that remain close to the equator. The LSP team goes to Vandenberg Air Force Base to run launches that require spacecraft to fly around the world in a north-to-south orbit, known as a polar orbit. LSP also conducts launches from Kwajalein in the Marshall Islands as well as Kodiak Island, Alaska and NASA's Wallops Flight Facility on Virginia's eastern shore.

To learn more about LSP, rockets and NASA missions go to:
http://www.nasa.gov/centers/kennedy/launchingrockets/index.html

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More ICON Information

More information about NASA's ICON mission can be found online at:

www.nasa.gov/icon
icon.ssl.berkeley.edu

And on the following social media accounts:

Hashtag: *#NASAICON*
Hashtag for June 13 NASA Social event at Berkeley: *#NASASocial*

NASA Heliophysics

Coverage: Detailed, continuous coverage of ICON throughout the days leading up to launch and through launch (with a focus on science); highlights from NASA Social event.

- Twitter: *@NASASun*
- *Facebook.com/NASASunScience*
- *YouTube: go.nasa.gov/sun-video*

NASA Kennedy & Launch Services Program

Coverage: Detailed updates on launch preparation and mission milestones.

- Twitter: *@NASAKennedy*, *@NASA_LSP*
- *Facebook.com/NASAKennedy*, */NASALSP*
- *Instagram.com/NASAKennedy*

NASA

Coverage: High-level posts about ICON in the days leading up to launch; launch coverage focusing on flight milestones.

- Twitter: *@NASA*
- *Facebook.com/NASA*
- *YouTube.com/NASATelevision*
- *Ustream.tv/NASAHDTV*
- *nasa.tumblr.com*
- Snapchat: *NASA*
- *Instagram.com/NASA*
- Google: *+NASA*

Understanding the Ionosphere:

NASA'S ICON MISSION

NASA's latest space mission, the Ionospheric Connection Explorer, otherwise known as ICON, will investigate the characteristics of the ionosphere—a unique region of Earth's atmosphere that makes radio and GPS communications possible. Space and Earth weather events, like coronal mass ejections and stratospheric warming events, drive extreme and unpredictable variability in this region. Understanding the forces at play in this zone will offer insight to the types of disturbances that interfere with radio communications and GPS signaling.

The Ionospheric Connection Explorer mission is a 2-year mission that will bring new insight to the dynamic nature of the ionosphere. The boundary where Earth and space weather systems meet in the ionosphere can create a turbulent mixture of neutral and charged particles, and this can interfere with radio and GPS communications. Headed by Dr. Thomas J. Immel at the University of Berkeley, California, the ICON mission consists of collaborations between several institutions.

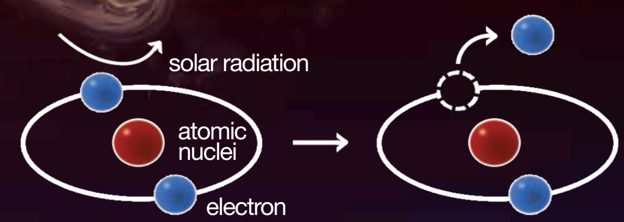


Figure adapted from http://ecetutorials.com/photo-electric-effect-and-photo-ionization/

IONIZATION

When solar radiation and/or cosmic rays enter the Earth's atmopshere, atoms and molecules can lose electrons to form positively charged ions. This process, known as ionization, creates a unique region in the Earth's atmosphere called the ionosphere, which contains a variety of ionized gas species, including ions of oxygen, hydrogen, nitric oxide, and others. These ions co-exist alongside the liberated electrons until they recombine through collisions.

IONOSPHERE

The ionosphere is a region of Earth's upper atmosphere, from about 60 km (37 miles) to above 1,000 km (620 miles) altitude. It owes its existence primarily to ultraviolet radiation and x-rays from the Sun, which ionize particles over a range of altitudes. The structure and composition of the neutral atmosphere that is ionized by the sun at these altitudes leads to a distinct set of layers in the ionosphere which vary in both ion species and total number of ions (right; Figure 1). Since ionization depends primarily on the Sun and its activities, the amount of ionization in the ionosphere is controlled by diurnal and seasonal effects (Figure 2).

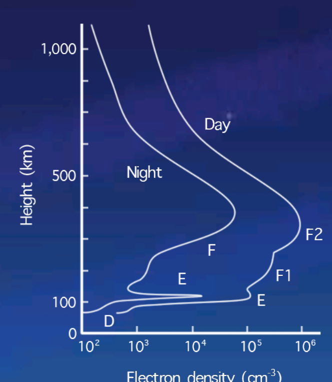


Figure 1: The density of electrons changes with altitude in daylight and nighttime. The F layer is generally the most dense ionospheric layer.

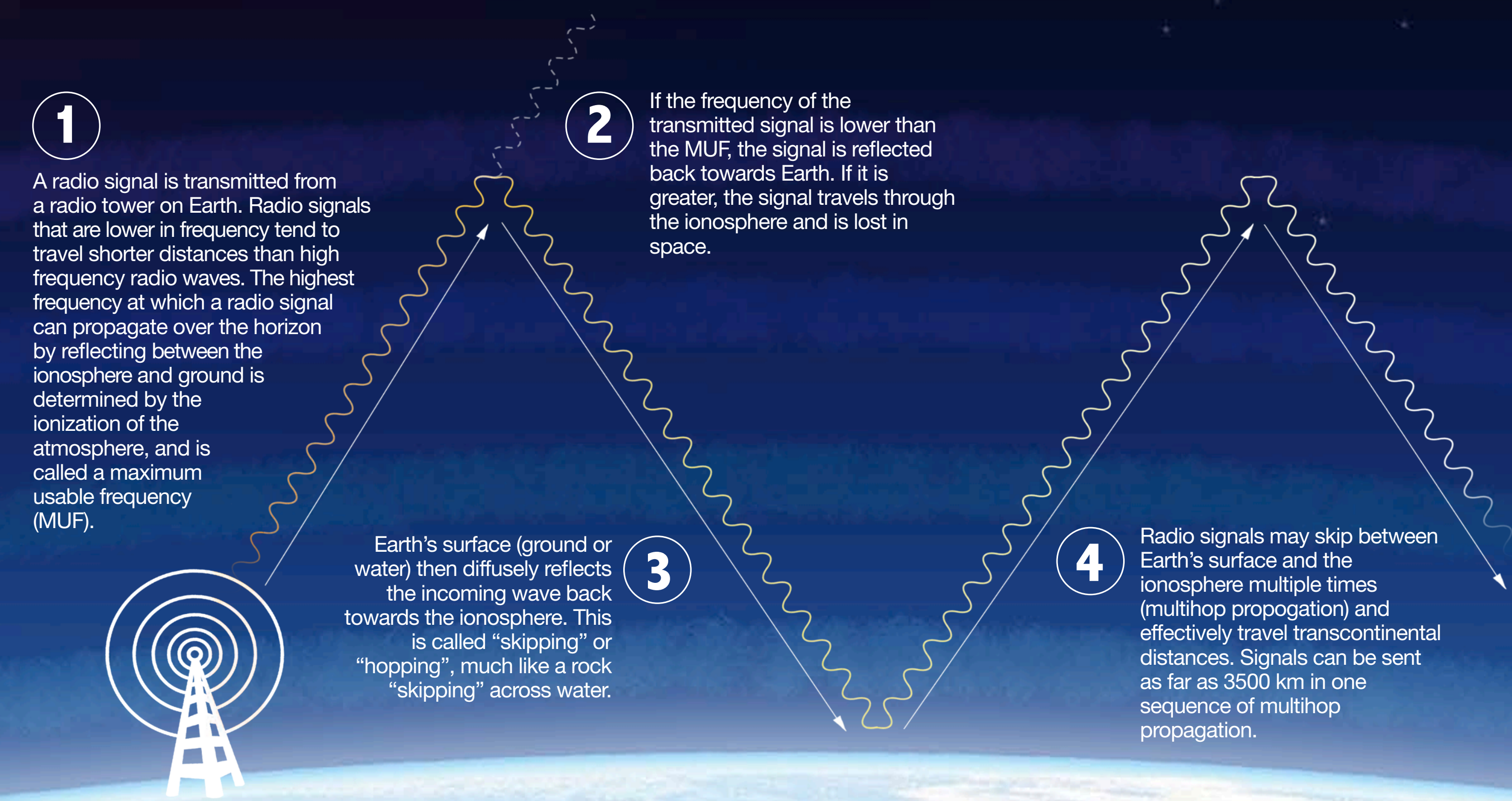
Figure adapted from http://encyclopedia2.thefreedictionary.com/ionosphere.

Figure 2: The ionosphere separates into different layers depending on the amount of sunlight available. Generally, the ionosphere is separated into four distinct layers during the daytime, and combines into two during the night.

Left figure adapted from the Naval Postgraduate School, http://www.weather.nps.navy.mil/~psguest/EMEO_online/module3/module_3_2.html. 22 October 2003. Right figure adapted from the University of Waikato, https://www.sciencelearn.org.nz/resources/243-space-plasma.

SKYWAVE PROPAGATION

Skywave propagation is the behavior of radio waves when they are transmitted through, or reflected from, the ionosphere back toward Earth's surface. Because low-frequency radiowaves (near the AM radio band and below) can reflect from the ionosphere, it is possible to send signals far beyond the horizon, traversing intercontinental distances. (This is how ham radio operators in the United States can contact operators in, say, Japan). However, since the ionosphere is a continuously changing region influenced by the sun and the neutral atmosphere, radio communications can change from one day to the next, and sometimes even from one hour to the next. Generally, layers with higher electron densities can reflect signals at higher frequencies, up to ~10 MHz for the densest portions of the ionosphere. The variation of the peak height of the ionosphere between day and night can often allow signals to propagate farther at night.



1 A radio signal is transmitted from a radio tower on Earth. Radio signals that are lower in frequency tend to travel shorter distances than high frequency radio waves. The highest frequency at which a radio signal can propagate over the horizon by reflecting between the ionosphere and ground is determined by the ionization of the atmosphere, and is called a maximum usable frequency (MUF).

2 If the frequency of the transmitted signal is lower than the MUF, the signal is reflected back towards Earth. If it is greater, the signal travels through the ionosphere and is lost in space.

3 Earth's surface (ground or water) then diffusely reflects the incoming wave back towards the ionosphere. This is called "skipping" or "hopping", much like a rock "skipping" across water.

4 Radio signals may skip between Earth's surface and the ionosphere multiple times (multihop propogation) and effectively travel transcontinental distances. Signals can be sent as far as 3500 km in one sequence of multihop propagation.

Credit: Mark Belan (www.artscistudios.com)

For more information,
please visit our web sites:

www.nasa.gov/icon

icon.ssl.berkeley.edu

NP-2018-4-189-GSFC (rev.11/2018)