Windows on Earth

Helping Astronauts and the Public Explore Earth from Space

Project Team

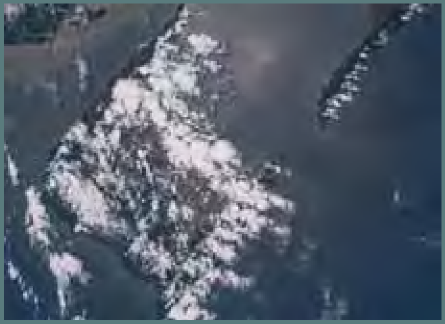
TERC

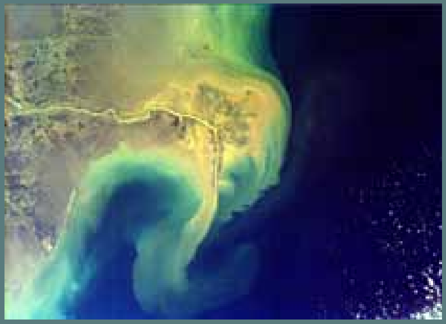
Association of Space Explorers

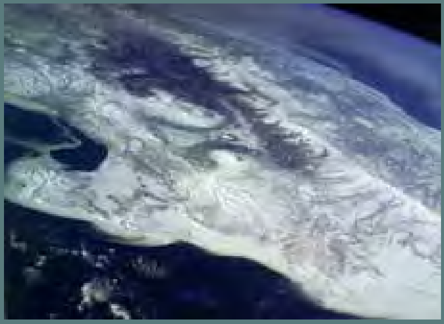
NASA Crew Earth Observation (pending)

Center for Advancement of Science in Space (pending)

v March 5, 2012







Seeing Earth with New Eyes

The view from space has fundamentally transformed our relationship to planet Earth. From the vantage point of astronauts, space stations and satellites, we see the world with new eyes. Instead of roads and buildings and borders, we see continents and the vast ocean. We see Earth's processes at work, as clouds form over land, storms cross the seas, volcanoes erupt and, vegetation changes with the seasons. We see the mark of human presence as cities grow and we tap into the resources of the land. And we see evidence of much larger scales of time and space, such as Earth's tectonic plates building mountains and moving continents.

Now this revolution in understanding Earth reaches beyond the realm of scientists and astronauts. It reaches our daily lives through the satellite images of daily weather forecasts, the views from above that accompany news stories, and the glorious pictures of Earth that grace a wealth of books, TV shows, museum exhibits and IMAX movies.

This view from above is also profoundly changing education. Throughout the world, students routinely use Earth visualizations to explore and learn about Earth. They do more than just read about plate tectonics or ocean circulation patterns; they see the processes at work. They inquire, explore and discover using this powerful new space-age perspective… just like scientists and astronauts. They learn to view beautiful Earth as a whole, as a dynamic system, marvelously interconnected.

And yet this eye-opening also reveals the global challenges that face humanity. From above, we bear witness to the loss of habitats through large-scale deforestation. We see urban sprawl, smog and open-pit mining. We see the challenges of water resource management, and the need for new sources of energy to support our growth and development. Increasingly, we also see the reality of global climate change, already evidenced by glacial retreat and sea ice break-up visible in astronaut photos and satellite images. We are at a crucial turning point in which our new space-age perspective enables us to recognize these global problems … and find new solutions.

The astronauts who benefited so much from their life-altering experiences now want to return the favor. The Association of Space Explorers, in collaboration with key partners, will launch a revolutionary set of Earth exploration tools to help students, scientists and the public. Windows on Earth will help scientists select targets and work with images, students and the public explore and learn from the images, and the astronauts themselves better manage their Earth observations and photography. This integrated package will help all of us experience the majesty of space and, from that unique vantage point, gain new insights about our home planet Earth.

Project Overview

Windows on Earth gives students, scientists and astronauts a new suite of tools for Earth observation and photography.

Windows on Earth is a suite of software tools to help students, scientists and astronauts explore Earth from space. It provides integrated tools to manage Earth observation targets, support on-orbit photography and help scientists and the public explore the wealth of images. The Earth visualization engine creates views of Earth as seen from orbit, with realistic features, colors, topography and day/night transitions. Scientists and astronauts use a comprehensive database of targets to set priorities and support on-orbit target identification. Students and the public use the web site to explore the astronauts' photographs, and help identify the most spectacular, engaging and informative images. The seamless integration of these components, and, at the core, the powerful simulator of Earth as seen from the International Space Station, enable a major leap over current tools used by scientists, astronauts, students and the public.

Windows on Earth was originally funded by the National Science Foundation as an educational program and on-orbit pilot test. With that funding, we created a museum exhibit (now in 4 major US museums) with an interactive simulation of Earth as seen from orbit, and a correlated web site for people to explore these dramatic photos of Earth. NSF also funded adaptation of the software for use on the International Space Station, as a window-side aide to help astronauts identify and photograph targets of scientific and educational value. The on-orbit software was successfully tested on ISS in October 2008, completing the original NSF project.

We now propose to build a new version with extended capabilities. This will include a full end-to-end integration, from selecting targets before the mission, managing targets and on-orbit photography, aligning and annotating images post-mission, and large scale public access through museums and via the web. We will also upgrade the core software engine, and each component will have enhanced capabilities based on lessons learned from the initial version. This new package will provide fundamental benefits to students, scientists, astronauts and the public, as they make more effective use of Earth photographs to explore, understand and learn about our home planet.

The team includes key scientific, educational, technical and astronaut partners. TERC, an educational non-profit with expertise in Earth science education, will lead the educational and technical development. The Association of Space Explorers will support the direct involvement of the astronauts. For this new phase, we have expanded this team to include NASA's Crew Earth Observation (CEO) program, who manage target selection, communicate targets to the astronauts and provide public access to the full archive of photographs. CEO will integrate Windows on Earth into their technology and operations.

On-orbit software helps astronauts identify targets

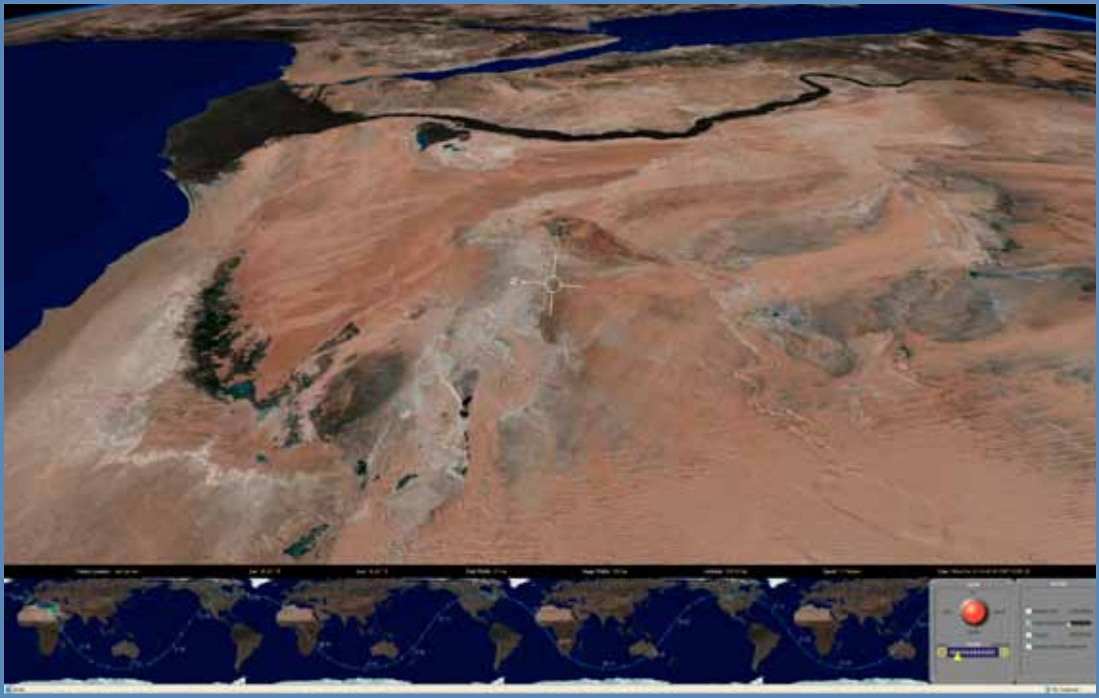
Web site helps students explore Earth

Windows on Earth museum exhibit at National Air and Space Museum

Windows on Earth features a state-of-the-art Earth visualization system. The Earth visualizer, based on an advanced software engine and comprehensive Earth imagery, all color-corrected for realism, lies at the heart of Windows on Earth. This core engine integrates all the Earth data, images, target lists and geo-referenced photographs. It forms the base of the full suite of educational, orbital and scientific interfaces and applications.

The ground-based component helps scientists select and manage target lists. Scientists need specific photographs for their research. They currently use several disparate tools to identify and manage targets, including Google Earth, physical atlases, a data base system, and calculations of projected orbital paths. Each day, they send to the astronauts a text file with descriptions and screen capture maps of a few selected targets, along with fly-over times. Windows on Earth will replace this multi-step process with a simple and integrated system that lets scientists scan the virtual Earth, zoom in on various locations, point-and-click to identify targets, annotate them and have the selections automatically integrated into the master target list. Based on current orbital projections, they can then prioritize targets and have the updated list sent to the ISS.

The on-orbit component helps astronauts on ISS identify targets for photography. Astronauts currently receive the day's targets as a text and image file. They study the text description and context, plan their day, and make sure they go to the window in time to take each selected photo. They look for the indicated features, often using a physical print-out of the target request (a challenging task, given the high speed of the fly-over). Windows on Earth will transform this process, by providing a window-side visualization tool that accurately depicts the current (and constantly changing) view out a given window, with each target clearly marked as it comes into view. A map of the current orbital path includes up-coming targets, and the time remaining until they come into view. By integrating the targets directly in to the view system, and accurately showing them on the virtual window, astronauts can take more photos, more easily.



Photorealistic simulation of Earth as seen from orbit

Window-side aide to help astronauts identify targets.

The photo alignment and annotation system helps scientists and the public use the images. Since each digital photo has a date and time stamp, Windows on Earth can recreate the view out the ISS window when the picture was taken. Scientists can then orient and align the image to its actual location, and add relevant annotations and feature tags. The geo-location and tags are then automatically linked to the image data file. This will greatly simplify what is currently a laborious process. It also opens up new possibilities to engage interested students and the public in helping to align and annotate the vast number of stored images. Many will find this a fascinating process. It will deepen the learning potential and serve the scientists in their subsequent work with the images.

The outreach component promotes environmental awareness and education, in schools, museums and a public web site. Through a combination of rich web sites, interactive museum exhibits, and educational learning activities, students and the general public will explore and learn from these photos. They will experience, vicariously, the same dramatic views of Earth as the astronauts, placing the images in a global context. We will feature hundreds of the most powerful and engaging images, but the public will also have access to the full archive of hundreds of thousands of photos, through NASA's Gateway to Astronaut Photography. With prior funding, we created a low-cost kiosk-based museum exhibit showing these large-scale views of Earth. We will expand on that exhibit with additional photos and astronaut commentary, and encourage museums around the of the world to purchase and install the kiosk. We will also link images of specific features with background information and educational interactives that help people understand Earth's basic processes All of this helps build a global consciousness, so essential for understanding and resolving vital environmental and global resource management issues.

Image alignment based on orbital path

Students investigate Earth science

Why Feature Astronaut Photos?

Astronauts have taken hundreds of thousands of photographs of Earth from space. Some of the images, such as the Apollo-era photographs of the whole Earth, have become icons of our times. Others have served scientists as essential research and documentation of our ever-changing planet. Many have supported public education about Earth. Almost all of them are striking for their sheer beauty.

From an artistic perspective, a recent Space Art show spoke of the emotional power:

"Seen from space, Earth presents an amazing palette of colors, textures, shapes and dynamic allure. We see the flowing waters and silt as the Mississippi River flows into the Gulf of Mexico; the deep structure of the Earth in a tectonic fault in Chile; the power of nature in the vast spirals and dramatic eye of a hurricane; the sparkling night lights of Italy; and the plume of an erupting volcano. What stories these photos tell and how deeply they capture our imagination!

The ones that work best, that speak from the heart of the artist to the heart of the viewer, have that magic that defines art as an expression that affects us, that transcends and transforms. Something the astronaut saw at that decisive moment. But let us give the real credit to mother Earth. This beautiful oasis, this ever-changing Gaia, this best-ever excuse to put windows on our spaceships and give cameras to astronauts."

From the scientific perspective, astronaut photography has some unique benefits. While satellites are scientists' primary source of Earth observation data, the astronauts' hand-held camera technology, coupled with the astronauts' observational skills, has some unique benefits:

Human judgment - First, the astronauts use their eyes, in real-time, from space, to notice phenomena, frame them in their cameras, and take the photos at the decisive moment. For example, for this picture of a hurricane over the Atlantic Ocean, the ground crew alerted the astronaut about the storm and the timing of the anticipated fly-over. Poised at the ready, he snapped the photo at this dramatic and telling moment.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Oblique perspective – The photo of Kluchevskaya Volcano erupting shows another benefit, the oblique perspective. While scientists usually prefer the top-down views typical of satellites for geo-referencing and spatial analysis, the oblique view reveals the surface topography. You can see the volcano rising above the surface among a cluster of mountains, and observe the plume as it spreads dramatically across the mid-level atmosphere. Research and experience confirm that people more readily grasp the 3 dimensionality with such oblique views.

Zoom from context to detail – Astronauts use multiple cameras and lens. They can easily zoom from a wide-angle image that establishes context, to a high-resolution close-up for details. For example, the telephoto image of Honolulu show striking detail of the city's structure, the coast and the airport runways. A context-setting wide angle view would show the chain of Hawaiian islands, resulting from their formation as the Pacific Plate passes over a sub-oceanic hot spot. Scientists use the astronauts' wide-angle views to help understand and communicate the larger context for their research.

Sun-glint – Other technical considerations provide real value for hand-held photography. In the image on the left of Lake Nasser, the bright sun-glint patterns reveal extent and structure of this dammed region of the Nile River. Ground crews can project the sun-glint location in relation to the orbital path, but it takes the astronaut's careful eye to time the photograph correctly.

Night Lights – In the image on the right, night lights show the sinewy path of the Nile River, as revealed by the pattern of lights of human settlement. Night light photography requires a sensitive camera, and careful panning as one flies over at 17,000 mph. The newest digital cameras on orbit have opened up this realm of photography, as has astronauts' growing ability to pan by hand or with a new mechanical device for this purpose. The net result is a wonderful archive revealing the rich variety of human settlement patterns around the globe.

When astronauts arrive in space, virtually all feel a transcendent emotion, a sense of awe, as they look out the windows and see our majestic Earth. Our goal is to help the rest of us, who haven't (yet) gone into space, gain that emotional shift, to see our world as a marvelous but finite, complexly interwoven package, in need of a bit more understanding and care from each of us.

Oblique View *(Kluchevskaya Volcano)*

Telephoto *(Honolulu)*

Sun-Glint *(Lake Nasser)*

Night Lights *(Nile River Delta)*

1. Help People Learn about Earth

"The first day or so we all pointed to our countries. The third or fourth day we were pointing to our continents. By the fifth day we were aware of only one Earth."

Astronaut Sultan bin Salman bin Abdul-Aziz Al-Saud

Our educational program combines web, school and museum services. We engage students and the public through a variety of resources, materials and services. The images themselves have a central role, with a variety of ways for people to access and explore them. Users learn what it is like to see and photograph Earth -- through the same simulated window views that the astronauts use. A new set of educational activities will feature hands-on use of the photographs, with students analyzing the images and trying to understand the features and processes at work -- just as the scientists do.

Three core learning goals. These goals apply to young people or adults, learning in schools, museums or on their own, in countries throughout the world. These goals align with commonly accepted science education standards:

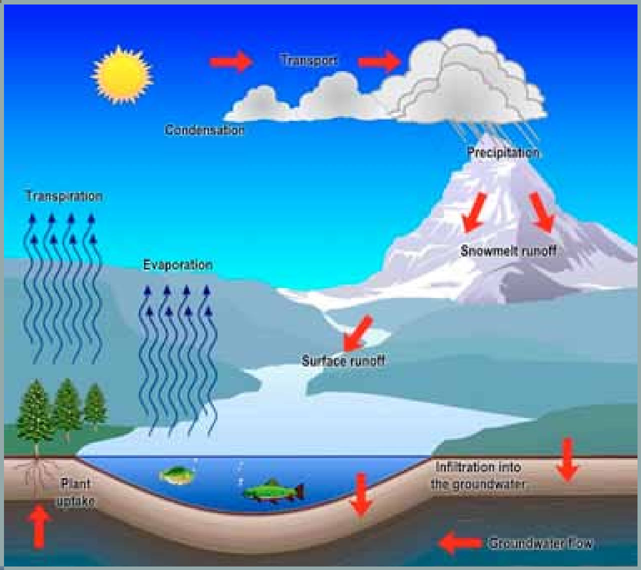
*1. Understand **Earth's features and processes**, as seen from space*
*2. **Think globally**, by seeing how Earth works as an interwoven system*
*3. Develop an attitude of **planetary stewardship** at local, regional and global scales*

Global services, reaching students in many languages. Since we want to build a global consciousness, we will provide images and resources for use anywhere in the world. The web has a global reach, and we will encourage widespread use of the Windows on Earth web site. We will provide the educational source materials to anyone who wants to translate to other languages, and freely post the translations online. Museums or science centers anywhere in the world can readily install the museum exhibit. The International Space Station is an international partnership, and global use of its assets is a vital core value.

The educational program has 4 components:

1. Web site simulates the view of Earth from ISS and provides global access to the images. Web visitors experience a simulated view of Earth as seen from a window on the ISS, calculated to match the actual real-time view. They also can navigate to any other part of the world. Throughout, selected locations are marked with links to highly engaging photos, with descriptive annotations. As visitors watch the Earth go by, they gain a sense of Earth's diversity of physical and natural features. They also see the human presence in the populated cities, agriculture and transportation routes. Visitors link thru to selected photos for more detail, many with voice-over commentary by the astronauts and scientists.

Reaching a global audience to learn about Earth



Understanding Earth as a dynamic system

Web site gives easy access to astronauts' photos

2. Museum exhibit provides easy ways to explore Earth.

The original Windows on Earth project created an interactive kiosk for use in museums. It features a large flat panel display to show the Earth as seen from orbit, with a joystick and push buttons to move around the Earth, zoom in and out, and turn on informative labels and data layers. It was deployed at several cutting-edge science centers, including the National Air and Space Museum, and has had remarkable success, with extended dwell times, and engaging conversations about what visitors see. We will update this exhibit with selected astronaut photos, along with voice-over commentaries by the astronauts who took them. The kiosk is an especially cost-effective way for museums to add a Windows on Earth experience on its own, or integrated it into other exhibits.

3. School services include high-value images and interactive learning opportunities. Adding on to the public web site, we will create interactive learning activities for use in schools. These will feature selected images that illustrate key concepts or clearly depict unique regions of the world. Students will experience Earth science by observing the flow of rivers, seeing the vast scope of a hurricane, connecting a line of volcanoes with a fault line, comparing cities around the world, and following seasonal changes in ice and snow cover. While some images are annotated, most are not. Thus, students experience some images as "mystery stories", using obvious and subtle cues to figure out what's going on – just like the scientists. We will provide collections of images and lesson plans around key themes, coordinated with essential learning goals. We will freely distribute the images and resources via the web.

4. "Citizen science" program will enable interested students and adults to review and catalog images. People who find the images especially fascinating and show talent in making sense of them, can participate in the actual cataloging of images. They will use a special feature of the web site, to align images to the surface topography, annotate features, and mark images of special clarity and visual power. This will be a vital service to the CEO team, who can't keep up with the volume of images, and to the scientists and public who use them. This work as "citizen scientists" serves real science, helps the participants learn more about Earth, and helps identify high value images for use in the other educational activities.

Museum kiosk is easy to install and engaging to use

“Citizen Scientists” will help catalog images

2. Help Astronauts Photograph Earth

"This is the best Earth Observations tool that I have ever seen. Other methods of determining location of photo targets pale by comparison."

Astronaut Jim Voss
STS 44, 53, 69,
STS 101-2/Expedition 2

Astronauts will use the On-Orbit system to show their current location and identify pre-selected targets. They will use the software as a window-side aide, with the software depicting a remarkably accurate simulation of the view out any selected window of the ISS. It has real advantages over the WorldMap mapping software already onboard the ISS, such as the integrated target list, the simulated window view, and tools for planning the next several hours or days of Earth photography.

Successful test on ISS demonstrated transformational value. Richard Garriott, a Space Flight Participant on ISS in October 2008, wanted to take photographs of the same locations his father, astronaut Owen Garriott, photographed from Skylab 35 years earlier. We worked directly with both Garriotts to adapt the software for use on ISS, and to integrate their selected targets. We also added targets from NASA's CEO scientists, and from the Nature Conservancy. During his flight, Garriott installed the software on a portable computer on ISS, and succeeded in photographing over a hundred of his priority targets.

Other astronauts provided essential design advice. During the initial development and after the mission, several members of the Association of Space Explorers reviewed the software. They were very impressed with its design, gave useful advice on improvements, and have advocated for its use as a permanent tool on ISS. The CEO team also has given crucial technical reviews and operational advice.

Rethinking how astronauts manage target lists. Currently, scientists select a few targets for each day, sending a text description, map and projected fly-over time. Astronauts study the information, set their watches and, at the designated time, go to the window to find the target and take the photos. With this new system, they can also do Earth observations, whenever they have the time, and photograph whatever targets are in view – up to dozens during a typical 45 minute daylight pass. The pilot test also clearly demonstrated the value of the accurately simulated window view – enabling astronauts to immediately identify each target.

At 17,000 mph, identifying targets takes concentration

GMT Site Lat Lon Lens
06:20:54 Perth, Australia 31.3S 114.0E 800

You have a near-nadir pass over Perth, the capital and largest city of the state of Western Australia. Weather conditions are predicted to be mostly clear. Overlapping mapping frames are requested as you traverse the urban center, located to the left of track (Fig. 1). Such imagery is useful for monitoring land cover and land use change both within the city center and along the urban-rural fringe.

Figure 1. Landsat true-color image of the Perth, Australia region as seen from an altitude of 339 km. Yellow arrow indicates your approximate orbit track.

Astronauts currently use static images and text

New tools will provide real-time computer display *(mock-up)*

Components of On-Orbit Display:

1. Window View, with marked targets, is the centerpiece.
Based on current orbital parameters, it shows a realistic window view, exactly matching the view out any selected window on the ISS. The ring marks what can be seen through that window (astronauts select among the several ISS windows, the software adjusts to the window's size and orientation). All visible targets are shown in the window, with a label box identifying the target and the preferred camera zoom level. The yellow scale bars show ground distance and the green boxes show the field of view for particular lens focal lengths. The software calculates sunrise and sunset times, and displays the daylight views or night lights accordingly. The astronaut can turn on and off labeling (to show national boundaries and labeling of major cities and key physical features).

2. Orbital Track is displayed in the lower left. For advance planning, it shows the next two orbits, on a world map, with all marked targets. The orbital track includes time markers showing where the ISS will be in five-minute intervals. It includes day/night. The map also projects day and night portions of the orbit. A circle around the current location shows the viewable area. In the next version, we will add projected cloud cover.

3. Next Ten Minutes view is displayed on the right side.
This regional map shows the current view and projects out to show the next 10 minutes along the orbital track (about 4,500 km). The circle at the bottom of the display corresponds to the window ring shown in the main window. The width of the projected path shows the full width visible if the astronaut gets right up to the window and looks as far left or right as possible. Upcoming targets are marked on the map, and a series of lines indicate the minutes until that location enters the field of view. A text box above the map lists current and up-coming targets.

Plan-ahead tools. The system also includes a multi-day orbital projection system, linked to the full target list, so that astronauts, and the ground-support team, can plan the best times for priority targets over the next hours and days. This includes day/night calculations, and forecast cloud cover, if available. Also, astronauts can add their own selections of priority targets, as well as daily updates of target lists from scientists and others on the ground.

Back on Earth, astronauts will use the simulator in their public presentations. As astronauts speak in schools, conferences, business meetings, community centers and other public venues, they often present some of their own favorite Earth images. In preparing this plan, some astronauts felt it would help to integrate Windows on Earth into their presentations, to convey the dynamics of observing Earth from space. Astronauts can pre-define a flight path they would like to demonstrate and describe. They also can link their own photos to specific locations to show them in context.

1. “Window View” exactly matches view out real window

2. “Orbital Track” on a world map with targets and day/night transitions

3. “Ten Minute View” shows up-coming targets

3. Help Scientists Study Earth

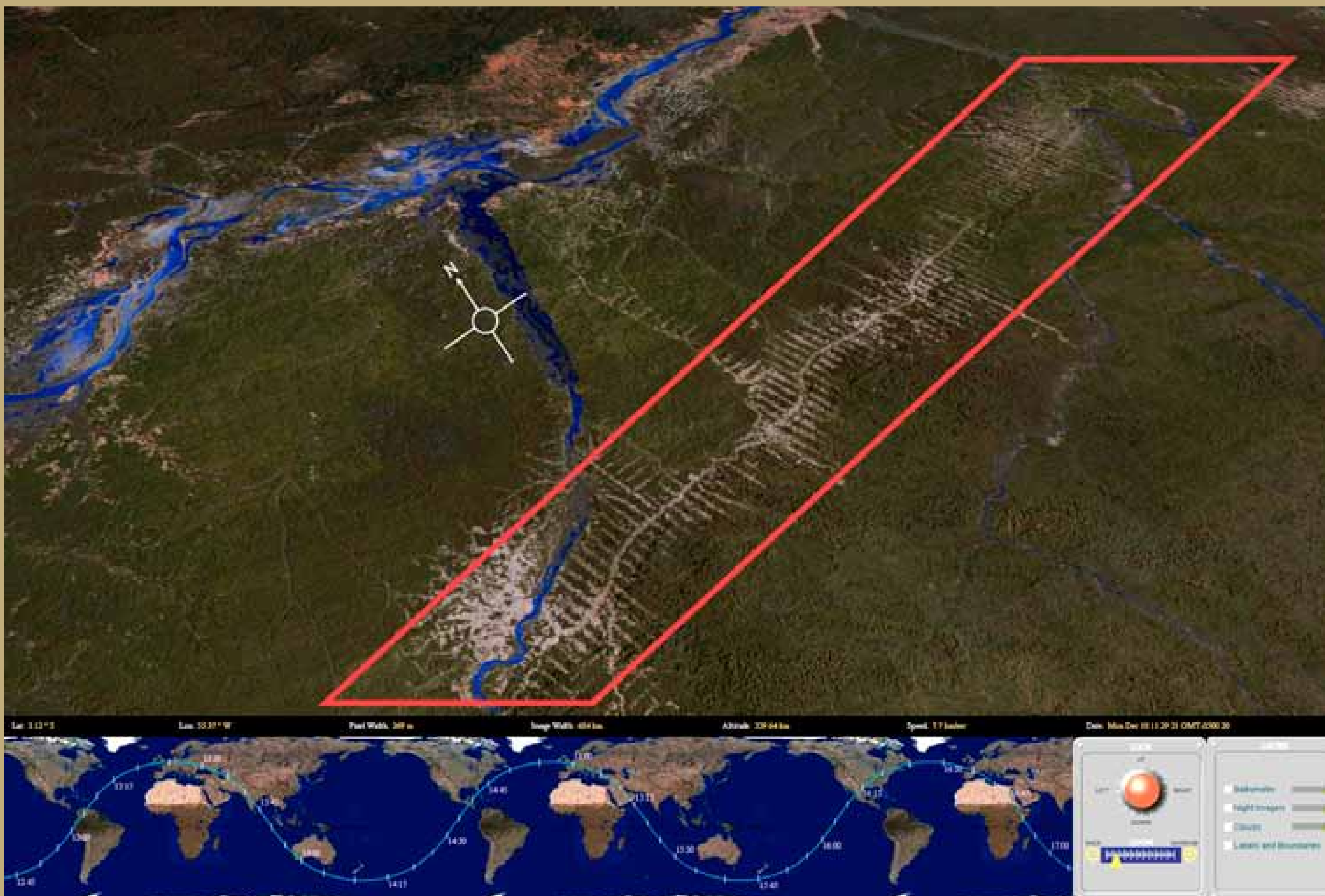
Scientists use astronaut photos in their research. Through the Crew Earth Observation program, scientists conduct vital Earth science research, using a combination of astronaut photos, satellite remote-sensing and ground-based data. Scientists study Earth's physical and biological processes, especially how the atmosphere, ocean, lands and biosphere change over time. They also study human geography, such as urban development and agriculture patterns. Increasingly, they focus on such environmental concerns as deforestation, surface mining and water resources, with a growing emphasis on indicators of global climate change, such as retreating glaciers and changes in seasonal patterns. While scientists identify many of the targets, the astronauts also use their own eyes and understanding of Earth to identify targets of opportunity.

Windows on Earth helps scientists with target selection and management. As an integrated system, Windows on Earth will provide a new tool to help scientists select new targets, using the software to zoom in on specific areas, correlate with existing photos, and set priorities for new photographs. They can mark new targets by pointing and clicking, annotate them, set priority levels, and have the new targets automatically integrated into the master target list.

New target lists are uploaded to ISS. Rather than send individual target requests to the astronauts, the full target list will be uploaded to ISS, and automatically integrated into the on-orbit software. As noted above, this enables astronauts to more readily identify and photograph the selected targets, and manage the overall target list as they take photos and identify new targets. Scientists can also the ground-based simulator to see the same view as the astronauts, helping them visualize and support the on-orbit photography.

Scientists can align and annotate images after downloading from ISS. Hundreds of new photographs are downloaded from ISS every few days, and it takes time to geo-reference each photo. However, since each image has a date and time stamp, Windows on Earth can calculate where the ISS was when that photo was taken, recreate that view, and provide a powerful new way to do this geo-referencing, and has tools to help orient and align the image to match how the astronaut was pointing the camera. As detailed in the education section, "citizen scientists" can be trained and supported to help with this time-consuming part of the process.

Scientists have access to the full set of images and context views to help in their research. Scientists can use Windows on Earth to help with their research, conveniently accessing the full set of images in NASA's archives. The visual and interactive system lets them click on a location, find other images of that location, select favorites, annotate the images, and link a series to show change over time.



Scientists can select new targets such as this deforestation

Astronauts' photos help scientists study how forest fires jump from one location to another

Astronauts' photos help scientists study the spread of a volcano's ash plume

Tech details: Software Architecture

Earth Viewer at the core – At the heart of the software is a core engine that creates Earth views, using the underlying Earth data, a set of view parameters, and calculation algorithms. The engine creates the view, based on a defined eye location (latitude, longitude, altitude) and a view frame (angle, size and orientation). The eye location changes as the ISS moves. The view frame changes based on the angle of view and zoom level. By dynamically generating a series of these Earth views, we create an animated fly-over, or a pan or zoom sequence.

Adaptable Interface – To create the range of applications for students, astronauts and scientists, we add interface elements (such as a look-ahead map) and controls for navigation and use. By sharing data, visualization tools and interface design across applications, we gain efficiency, flexibility and ease of use.

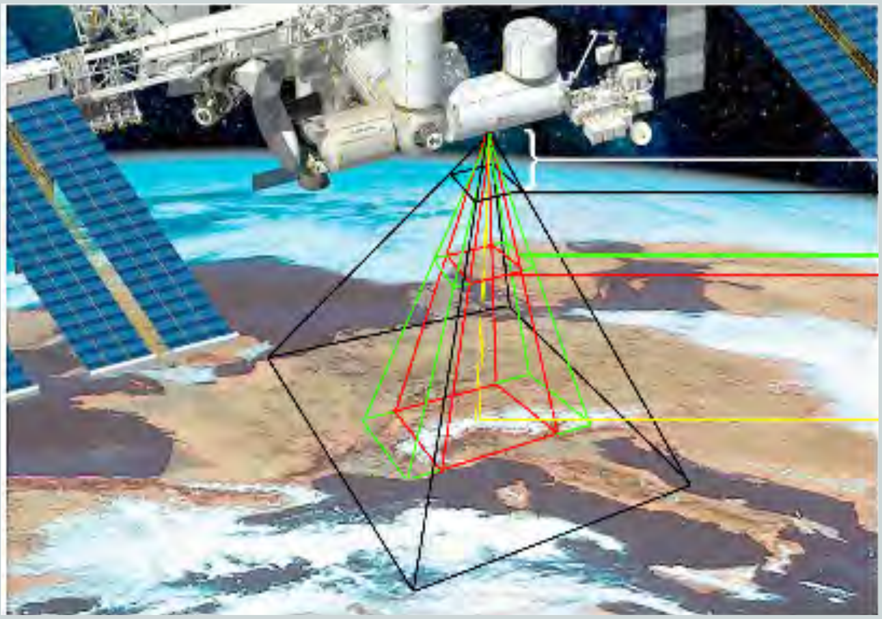
Modular structure – As illustrated in the software architecture chart, we organize the underlying data and tools into four groups:

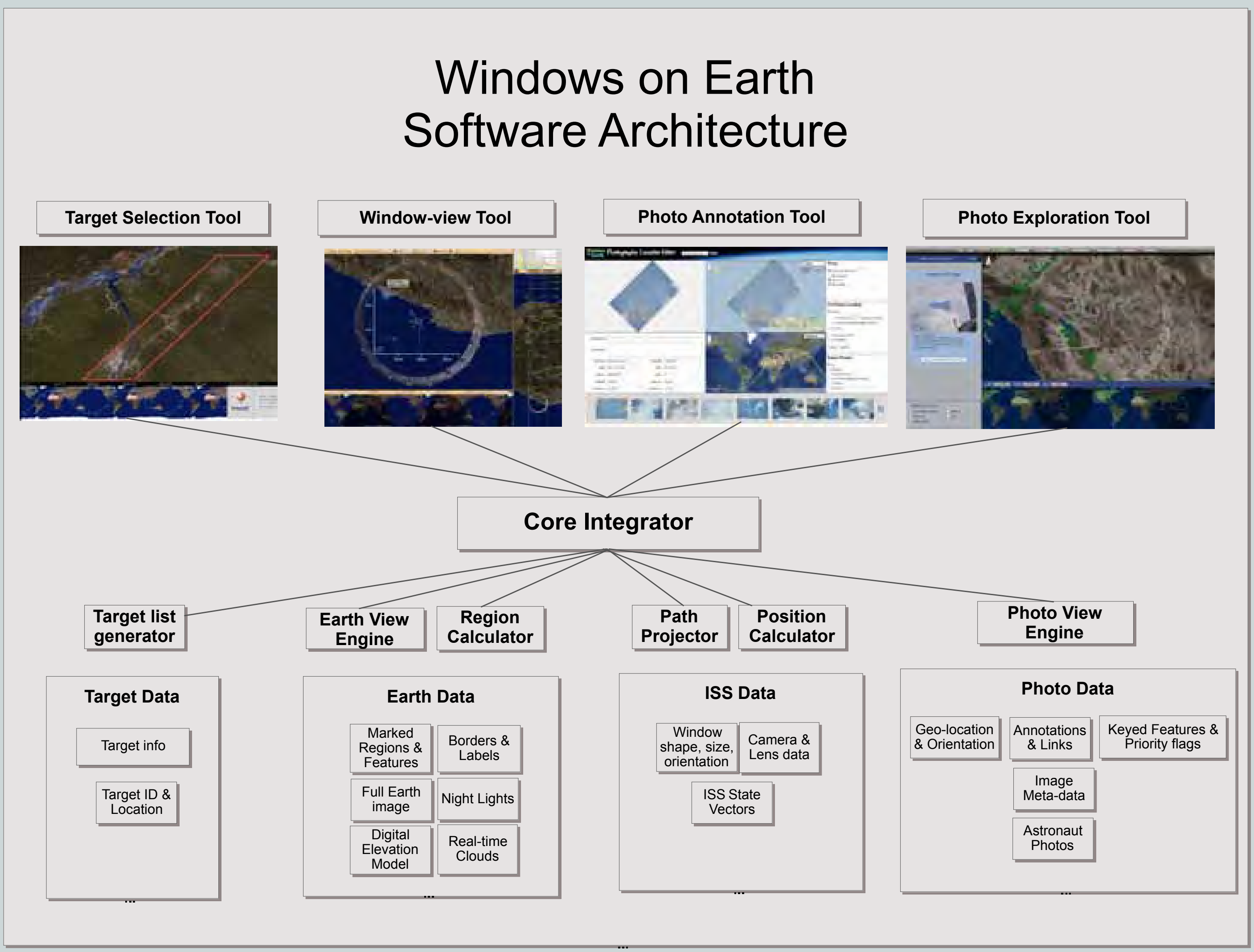
1. **Earth** – Earth imagery and overlays, along with the Earth visualization engine
2. **Targets** – List of targets and metadata, along with target list management tools
3. **ISS** – State-vectors for ISS location and associated path and view algorithms
4. **Photos** – all photos, with metadata and tools for geo-referencing and displaying

Core Integrator – The central software manages the whole system, with each activity or application integrating the specific data and tools, into an interface appropriate for each audience.

Built as Web Sites – Each application is built as a real or virtual web site, operated through a browser. The public web site and photo annotation tools are accessible through public URLs. The museum exhibit and on-orbit tools use their own web servers, locally operated on the computer running the application.

Version 2 Rebuild – For Version 2, we will do a major rebuild that takes advantage of new software development tools and environments, and builds on lessons we learned in Version 1. For example, in Version 1, we built each component as a separate application, only partially sharing code elements. In Version 2, we will implement the common core and fully integrated components. Also, we will shift to HTML5 as the top-level environment, and discontinue use of Flash, to give us state-of-the-art tools. We also will shift from GeoFusion's Earth visualization technology, to a more flexible set of tools that do not require plug-ins or ActiveX controls. Collectively, these changes give more stability, more efficient coding, flexibility in tool and interface design, and portability to additional platforms.



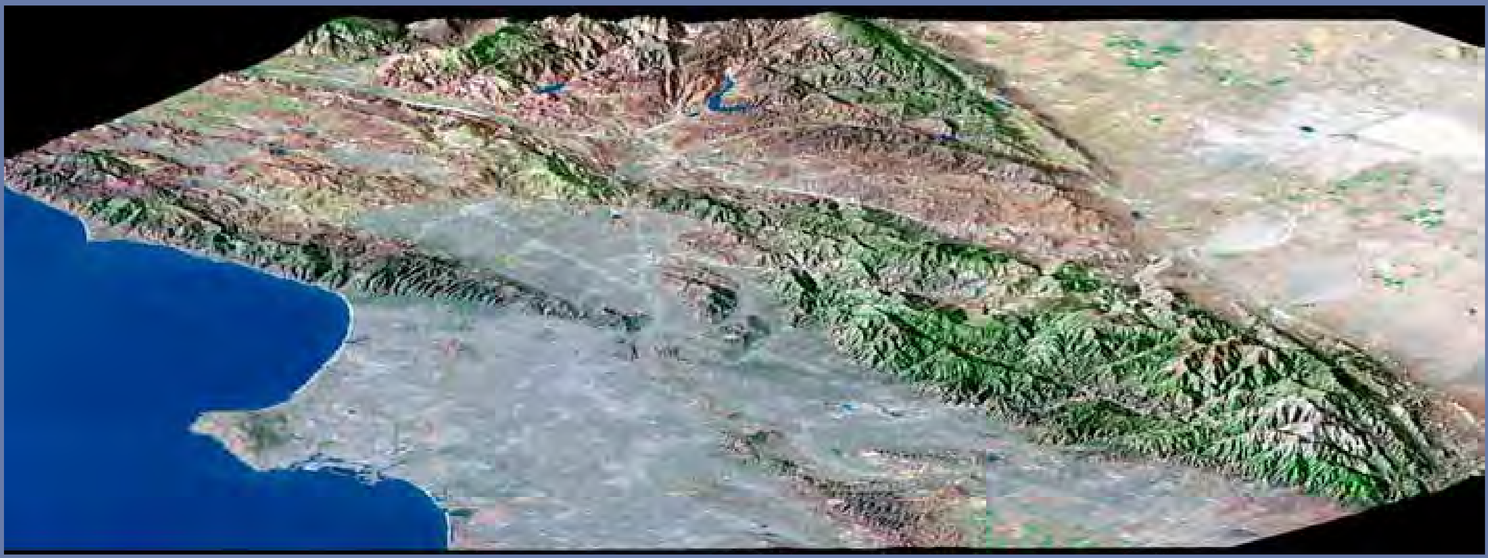

Windows on Earth
Software Architecture
Target Selection Tool
Window-view Tool
Photo Annotation Tool
Photo Exploration Tool
Core Integrator
Target list generator
Earth View Engine
Region Calculator
Path Projector
Position Calculator
Photo View Engine
Target Data
Target info
Target ID & Location
...
Earth Data
Marked Regions & Features
Borders & Labels
Full Earth image
Night Lights
Digital Elevation Model
Real-time Clouds
...
ISS Data
Window shape, size, orientation
Camera & Lens data
ISS State Vectors
...
Photo Data
Geo-location & Orientation
Annotations & Links
Keyed Features & Priority flags
Image Meta-data
Astronaut Photos
...
...

Tech details: Earth Visualization

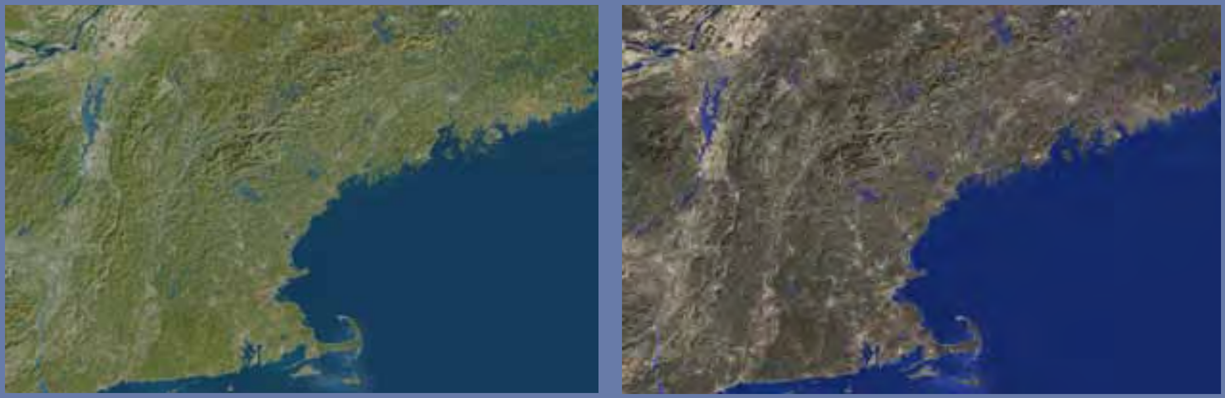
Layers of Data - The Earth view system drapes a detailed photocomposite digital Earth onto a 3D Digital Elevation Model, along with geo-referenced data and related overlays. The DEM provides the altitude information, enabling 3D relief views of surface topography. The Earth imagery, based on global satellite data, provides the photo-realistic views as seen from above. The data overlays add borders, captions, clouds and other useful information.

Photorealistic Earth - The satellite imagery deserves special comment, because of its high quality. It provides an exceptionally accurate color representation. WorldSat, our imagery partner, used proprietary algorithms to seamlessly combine data from multiple satellites, into a high-resolution global data set. We then worked with astronauts (notably Dr. Jay Apt) to adjust the color representation to match their perception of Earth as they saw it from orbit. For example, satellite imagery typically shows vegetation as a vivid green (left image above) whereas the actual color is more of a grey green (right image above). Also, we have smooth transitions across multiple levels of resolution (30m for the full globe, 1m for more details in selected locations), enabling a natural feel to panning and zooming around the Earth.

Night and Clouds - We add a night-lights layer (1km, derived from Defense Meteorological Satellite Program (DMSP) satellites), and calculate the transition from day to night, based on the specified date/time of the ISS. For cloud-cover, we currently use a sample set of data as illustrative. In version 2, we will add the ability to update to current cloud cover data. This is easily done with the ground-based application. For the ISS on-board application, we will provide updated cloud cover information as frequently as allowed by NASA data communication protocols.



Earth imagery draped over 3D Digital Elevation Model



Colors corrected from artificial bright green (left) to more realisic grey-green (right)

Real-time clouds and calculated day/night transition

Tech details: Earth Photographs

One Million Photos - Since the dawn of the Space Age, astronauts have taken over one million photographs, from the John Glenn's first pictures using a simple film camera, to state-of-the-art high-resolution digital images from the advanced cameras now on ISS. NASA archives these images at Johnson Space Center, with most of the images available through Gateway to Astronaut Photography website.

Digital and Film - The digital era has revolutionized this photography, since astronauts can now take the pictures, download them directly via the TDRSS satellite network, and have them added to the full archive – all in near real-time and without any loss of quality. On the other hand, film images have to be scanned in order to post them digitally – a large and expensive task. While NASA has scanned and posted 1.2 million images, our work in this project focuses on the 700,000 digital images (this number grows an average of 10,000 images per month). The digital images have an extra advantage – each includes a date and time stamp in the metadata that enables us to back-calculate where the ISS was when that picture was taken.

Annotations - NASA scientists review the images for their own research and to benefit others who might want to use. They geo-reference them to the exact location, rank them in terms of quality, cloud cover and other factors, and add annotations about the features in the images. This is a huge task, so we propose adding a component of our educational work that will enable students and the public (trained online) to do this geo-referencing and annotation. This "crowd-sourcing" will engage interested people in powerful learning, and provide a service to the scientists.

Targets - In terms of the target list, NASA-based scientists have selected the targets based on their needs and priorities for Earth observations. Based on a NASA-approved process, we also add targets selected by research partners (such as the Nature Conservancy) and students. The astronauts themselves also add some of their own priority targets. Each target has a location, description, preferred lens, and priority level.

Bay of Bengal mangrove tract

Tech details: Education

Museum Kiosk – We developed a standard kiosk for use in museums. It has a large flat panel to show the Earth view, a joystick to move around Earth, zoom in and out buttons, and a small touch screen to control overlays and jump to locations on a map. The physical structure is made of aluminum, with an overall footprint of 142cm wide x 107cm deep, including built-in space for the computer. The kiosk can be easily installed – all it needs is power and internet access. A fabrication contractor can readily manufacture the kiosk individually or in multiples. It also is possible for a museum to design its own cabinet or structure for the basic components (display, joy stick, buttons, touch screen).

Web site – The web site has several components. First, it recreates the same experience as the astronauts, with the animated window view, orbital path, and, ten-minute projection and marked targets. This helps students and the public understand the on-orbit experience of Earth observation. Second, it provides a viewer to explore the photographs, with the ability to select by location or theme. Third, it provides background information on Earth science concepts, as illustrated by the images. Fourth, it has a tool for users to align and annotate images, as a service to scientists and other users. (URLs: *WinEarth.terc.edu* for basic web site; *issphoto.myflipside.net* for photo-editor)

Learning Activities – We currently link to Earth observation learning activities developed by TERC, ASE, NASA and others, available though our own web site, and external sites such as the Gateway to Astronaut Photography, ISS EarthKAM and other projects. For Version 2, we will create a new set of learning activities that extend and deepen this learning, with a special focus on key concepts in Earth system science, as illustrated by the astronauts' photos, and the Earth visualization system.

Museum kiosk is easily installed

Web site simulates ISS window view

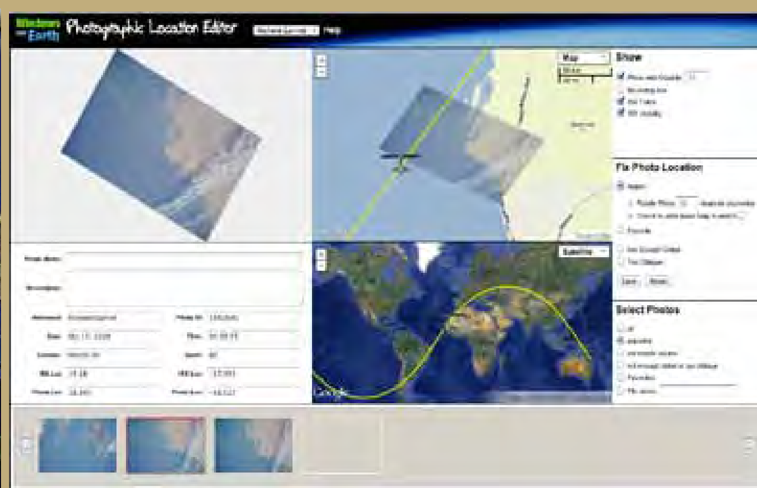


Photo-Editor lets students align and annotate images

Learning Activities help students learn about Earth

Tech details: Int'l Space Station

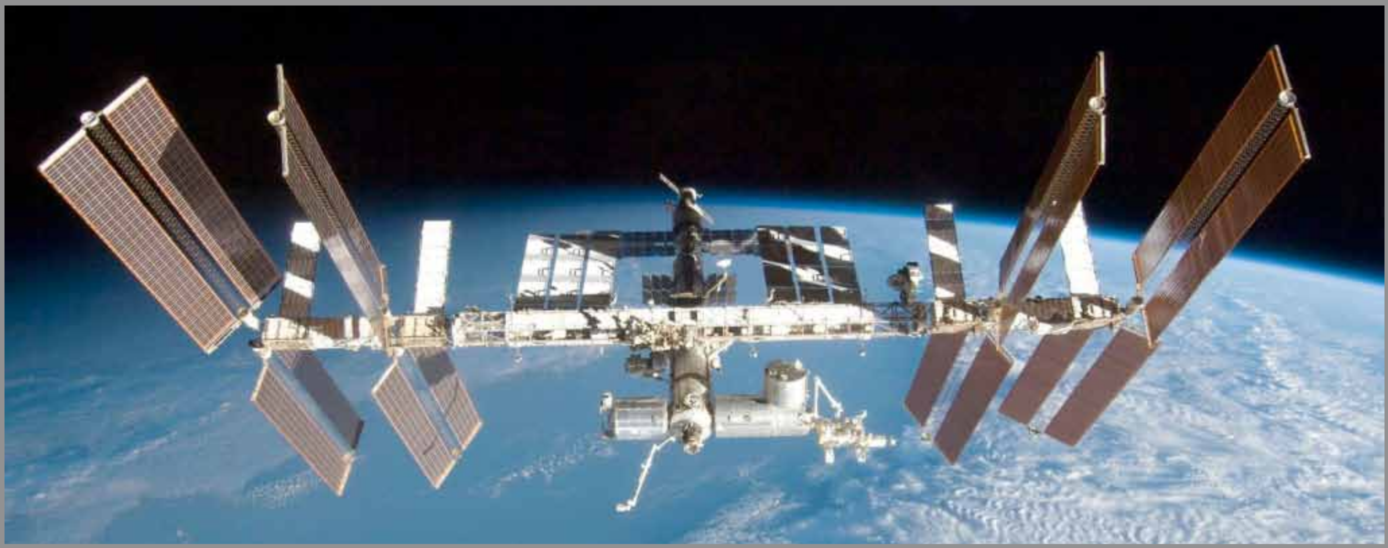
Calculating ISS location - Based on orbital parameters, we calculate the location (lat, lon, alt) of the ISS, either currently or at any given time in the past or projected for the near future. NASA provides the current and archived parameters, which change as the ISS orbit degrades or is re-boosted. We use these calculations to let the view engine know the ISS location. We also use them to generate projected orbital paths. Since digital cameras embed a date and time stamp in the metadata for each image, we can also do a reverse calculation, to determine the location of the ISS when an astronaut took the picture. (Note: we do similar calculations for shuttle flights, based on archived shuttle flight data.)

ISS Windows – ISS has multiple windows, that vary in size, orientation and optical quality. Astronauts often use the large 51 cm window on the US Destiny Lab, because of its size and high quality glass. On the Russian Zvezda module there are smaller but also high quality windows. Both of these are typically oriented to look at Earth. Some crew quarters have side-looking windows giving an oblique view to the horizon. And the new cupola (shown at the end of this document) gives a dramatic, panoramic views of ISS, Earth and the night sky. Windows on Earth lets the astronaut select the window of choice, and it automatically adjusts to the size and field of view for that window. Version 1 did not include the cupola, version 2 will.

Cameras – Astronauts use several digital cameras on ISS. Most typically they use a Nikon D3X or Kodak DCS760, both standard DSLR digital camera. They use fixed and zoom lenses, up to a 400mm focal length, with a resolution of 5m/pixel at the typical ISS altitude. While they can use a 2x extender, it requires very careful panning to avoid blur, given the high speed of the ISS.

Data Communications - Ground support communicates with ISS via the high-speed data channels of the TDRSS satellites. While TDRSS Ku-band has a capacity of 300Mbits/sec, the laptops communicate with the ground at 3Mbits/sec up and 10Mbits/sec down. Astronauts download images on a daily basis. We will use the uplink to upload new target lists and cloud cover layers.

Computers - This software will operate on the computers already on ISS. In our pilot test in 2008, Richard Garriott took the software to the ISS on his crew Personal Storage Device (PSD) – a hard disk that he installed on the Lenovo A31 assigned for his on-orbit use. That computer was not connected to the ISS network. Assuming NASA approval, we will similarly deliver the new software on a PSD, physically carried to ISS, but would have it securely connected to the network, to facilitate updating state vectors, target lists and current cloud cover.



Version 2 - Summary of new features

Major Rebuild - We will do a major rebuild of the full system. The interface and operational design will stay essentially the same (plus the enhancements listed below). However, we will take advantage of lessons learned in version 1 to have a cleaner architecture, fully shared and integrated components, and use new web tools, such as HTML5. We also need to replace the GeoFusion visualization engine, with a more stable 3D visualization toolkit. All applications will use this new rebuild.

Target Management System - We will create new tools for selecting and managing targets. This will help the scientists and astronauts (for use on orbit), yet it will also provide ways for students and the public to suggest new targets.

Photo editing system - We will revise the photo editing system, in which users geo-reference and annotate images. We will improve the user interface and work thru details of direct linkage with the full archive of astronauts' photos. We will establish the crowd-sourcing for students and the public to align and annotate images, and set priority levels for the most compelling and informative images.

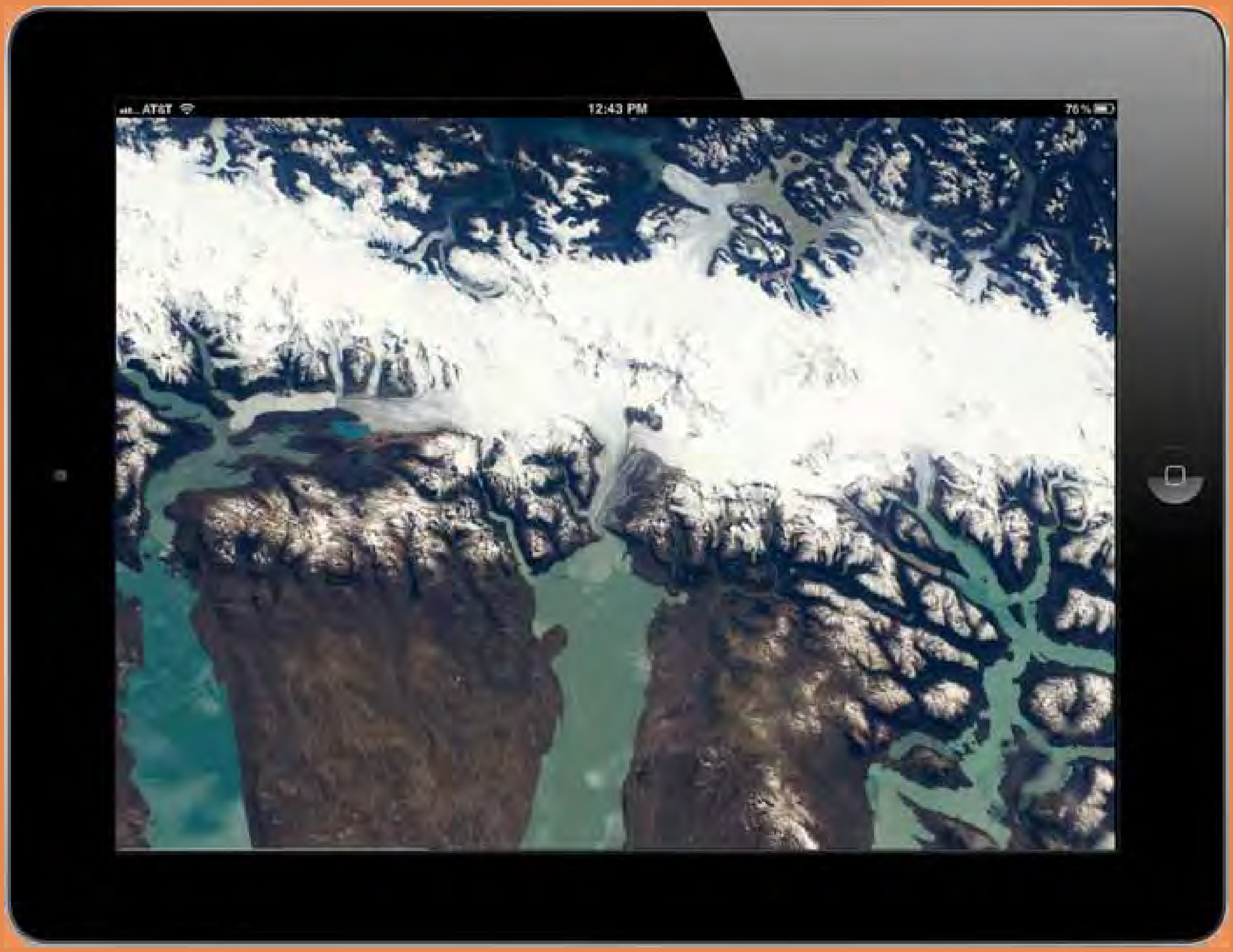
Guided Tours for Education - We will improve our design of the guided fly-over tours, in which a series of images illustrate key features and concepts in Earth system science. This will also include audio commentary by astronauts and scientists, as if they were tour guides for people observing Earth from ISS.

On-Orbit tools - We will do careful design and testing of the on-orbit version so that it works on the new computers on ISS, and has a completely safe interface to the ISS network. We will enable uploading new target lists directly to the software. We will also develop a system to upload cloud cover images and projections.

Museum Exhibit - We will add geo-referenced on-screen hot points so visitors can click and see especially compelling photographs, including commentary by astronauts and scientists. We will also translate navigation controls and explanatory information to other languages, for use in museums around the world.

Web site - We will redesign the public and educational web site, based on feedback from users. This will include simpler navigation controls, expanded commentary by astronauts, additional educational activities, and a friendly interface into the full set of astronauts' images

Apps for SmartPhones and Tablets - With the rebuild of the core engine, we will be able to make specialized apps for use on SmartPhones and tablet computers. We will adapt WinEarth displays for the basic functions to work on these devices. We expect that the simulated view of Earth as seen from the ISS's current location will be especially popular.

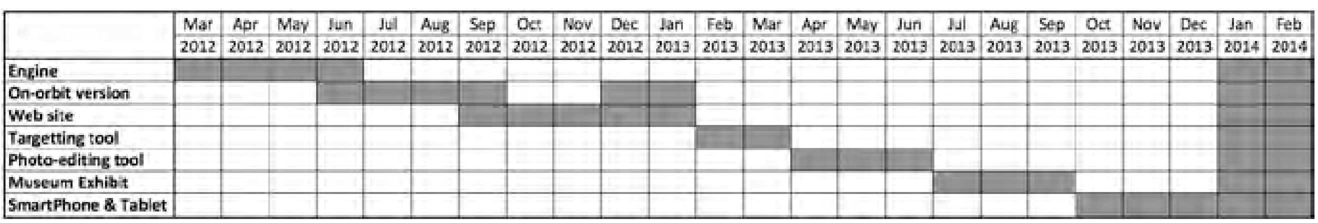


Snow-covered Andes Mountains – displayed on iPad

Draft Timeline

Assumptions and Key Dates - Actual timeline depends on the start of funding for development work, the scope of funded work, and desired launch dates for the new web site, museum, science tools and on-orbit use. The timeline below assumes funding for the full scope of work over 2 years, and the following key dates:

Mar 1, 2012	Development begins
Oct 1, 2012	On-orbit version ready for tech review
Nov 1, 2012	ASE Congress - demo web & on-orbit version
Dec 1, 2013	Public web site goes live
Feb 1, 2013	Targetting tool used by scientists
Mar 1, 2013	On-orbit version launch on Expedition 35
June 1, 2013	Photo-editing tool goes live
Oct 1, 2013	Museum exhibit done
Dec 1, 2013	SmartPhone & Tablet tools done
Mar 1, 2014	All components done




WINDOWS ON EARTH

Development Team

This project involves a collaboration of several organizations and individuals, each with a key role. They have worked together in the design, planning and development of this project, and will collaborate in the remaining implementation, deployment and dissemination.

TERC will lead development. TERC is an educational non-profit based in Cambridge, MA and was the lead organization on NSF grant for Windows on Earth Version 1. Daniel Barstow, Senior Principal Investigator, will be the TERC lead.

Association of Space Explorers is the co-lead and will serve as liaison to the astronaut community for policy-related issues and to engage astronauts who might add additional imagery and audio commentary to the system. Andy Turnage, Executive Director of the Association of Space Explorers, will be the ASE lead.

NASA's Crew Earth Observation Program manages Earth observations, conducts scientific research, archives the images, and operates the public web site. CEO will assure tight integration of Windows on Earth with current methods and resources, and provide direct linkage to the Gateway to Astronaut Photography.

WorldSat provides the global data imagery, color-corrected for accurate representation of Earth.

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