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EARTH SYSTEM MONITOR

A guide to NOAA's data and information services

NOAA's multi-sensor fire detection program using environmental satellites

An important new capability reaches operational status

INSIDE

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Biomass burning has tremendous impact on the Earth's ecosystems and climate, for it drastically alters the landscape and biologic structure, and emits large amounts of greenhouse gases and aerosol particles. Smoke aerosols may interact with cloud droplets and alter considerably the earth's radiation budget. Remote sensing is the most efficient and economical means of monitoring fires over large areas on a routine basis, despite that it suffers from various limitations. Satellite observations can provide timely information on both fire development and fire damage following fire. Remote sensing of fires also has the potential to help authorities make decisions regarding fire fighting and reducing the impact of fires on the population.

Natural boreal and temperate forest, brush, and grassland ecosystems evolved and adapted with wildland fire (or wildfires) as an agent of ecological change. Human development has altered many natural landscapes and placed people in direct contact with wildfires at the so-called wildland-urban interface. Wildfires cause loss of human life and personal property, economic upsets, and disturbances in regional and global atmospheric composition and chemistry, and climate. Fire managers wish to respond appropriately to best protect and preserve the resources at risk. According to the National Interagency Fire Center in Boise Idaho (*http://www.nifc.gov/information.html*), so far this year over 6 million acres have burned in the U.S. due to wildfires. The cost to fight these fires this year will be well over one and a half billion dollars.

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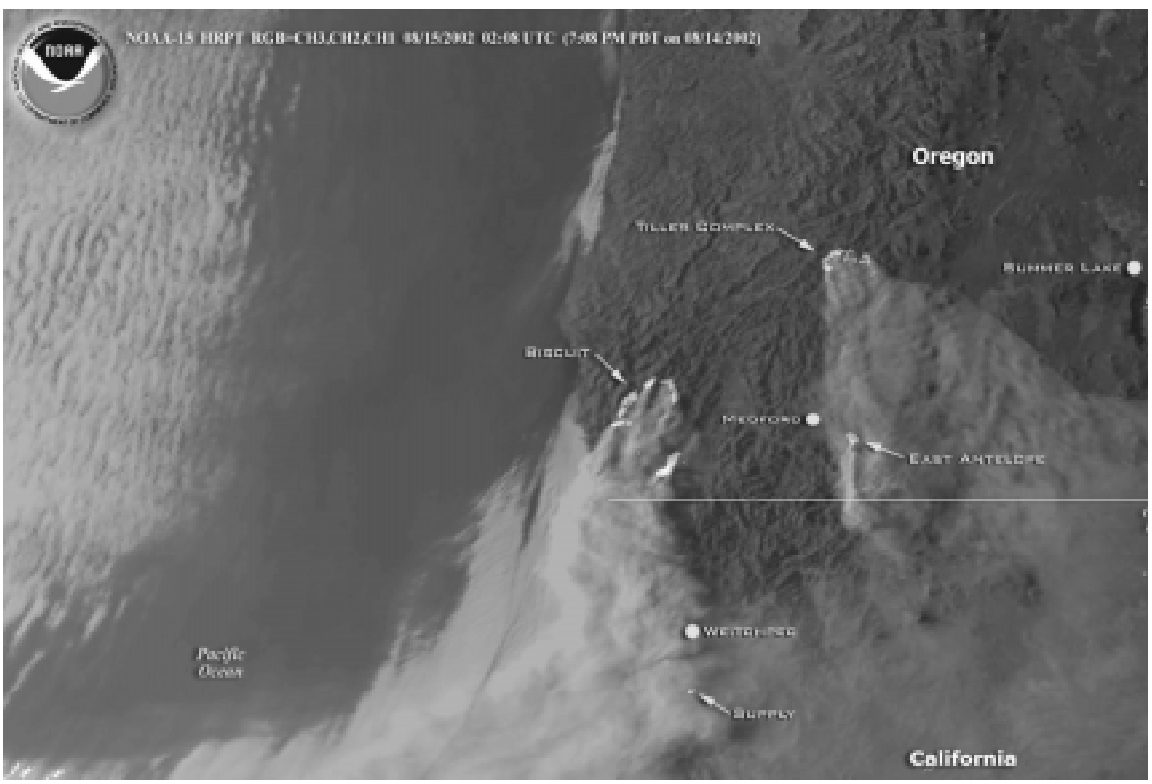

▲ **Figure 1.** This image of fires was made by NOAA's Operational Significant Events Imagery program using AVHRR data from NOAA-15 on August 15, 2002. Fires appear as bright white. A great deal of smoke can be seen emanating from these fires in Oregon and California. (Image created by Jason Taylor)

U.S. DEPARTMENT OF COMMERCE
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Background

The capability to detect fires from space using environmental satellites has long been appreciated, and investigations at National Environmental Satellite, Data and Information Service (NESDIS) have been conducted for over twenty years. Matson and Dozier (1981) demonstrated the ability to detect and characterize sub-pixel resolution fires. Matson *et al.* (1984) correlated satellite derived hot spots with confirmed ground observations, and Matson *et al.* (1987) presented a summary of satellite detection capabilities. Satellite images of fires and smoke have been produced routinely within the Satellite Services Division (SSD) since then to demonstrate detection capabilities.

In the Summer and Autumn of 1997, concern over pollution caused by smoke from extensive wildfires in Indonesia prompted requests from United Nations aid organizations for routine imagery of fire and smoke in the area, and for a period of several months, this was accomplished. Also in 1997, the volume of special requests for fire imagery prompted SSD to propose the implementation of an operational program, wherein contract personnel would routinely process satellite imagery of many environmentally significant occurrences, including fires, under government supervision. The proposal was funded, and the Operational Significant Events Imagery (OSEI) program commenced in early 1998. Since then, fire managers at federal and state agencies have often used OSEI images in fire detection and monitoring.

The Spring of 1998 saw wildfires burning out of control across large tracts of Florida, Mexico and other parts of Central America. Many of the fires across Central America were started in order to clear agricultural areas but quickly burned out of control. The resultant large smoke plumes brought a pall to a large section of the U.S. that extended from Texas to the Mid-Atlantic states. The Florida fires caused considerable damage, destroying a number of homes and closing portions of Interstate highways.

In response to this emergency, SSD began producing a regular analysis of smoke plumes and fire hotspots over the Gulf Coast states, Mexico, Central America and the Gulf of Mexico during the 1998 fire season. This was initiated on an ad hoc basis but plans were quickly drawn up to initiate a smoke and fire analysis that would incorporate all of North America. However, it would take a few years to realize this goal due to hardware, software and staffing constraints. The product that did emerge was a regional graphic that was made available to users via the Internet. It was produced manually twice per day and could cover either the same regional area twice or two separate areas, depending on the fire situation.

This smoke and fire product relied heavily on satellite imagery from NOAA's Geostationary Operational Environmental Satellite (GOES) series. This platform allows for at least half-hourly detection of these hazards over the U.S. The frequent temporal updates allow for detection of fairly short lived fires (up to a couple of hours) as well as fires that have intermittent cloud cover over them. The primary satellite bands that are employed are in the visible wavelengths for smoke detection and 3.9 microns for sensing fires. The resolution for GOES is 1km at satellite subpoint for the visible channel and 4 km at subpoint for the 3.9 micron channel (and all other thermal bands). However, resolution gradually decreases as zenith angle increases such that the effective resolution over large parts of the US is actually 5 or 6 km.

The 3.9 micron channel is preferred for fire detection over the 10.7 micron window IR channel used for many other meteorological applications due to its sensitivity to high temperatures at the subpixel level. This difference in sensitivity can be illustrated by comparing the response in the two wavelengths to a 500K fire which occupies varying amounts of a pixel scene and inserting it into a background

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EARTH SYSTEM MONITOR

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NOAA to support international study on commercial space policy

NOAA's Commercial Remote Sensing Licensing Team will support a new study being conducted by the Organization of Economic Cooperation and Development (OECD), entitled "The Commercialization of Space: Long-term Prospects and Implications." The study will address a number of commercialization issues which governments must address in the coming years, to ensure the further commercial development of the space sector and realize its socio-economic potential. Most notably, the OECD study will attempt to determine the best roles for the private and public sectors in space, and recommend rules for space's further commercial development. NOAA expects the OECD study to provide useful information on the further development of the commercial remote sensing industry, and recommendations to facilitate a more uniform international business.

U.S. - Russia cooperative NATO grant

A grant was awarded by the North Atlantic Treaty Organization (NATO) to a NOAA research scientist to develop a cooperative program with Russian Academy of Sciences' institutions. The program, entitled "Data Base of Catastrophic Droughts in Russia from NOAA/AVHRR Data," was selected for funding in order to stimulate research and applications of early detection and large-area assessments of catastrophic droughts, environmental disasters which have been affecting Russian agriculture, forestry, and economy every 3-4 years.

This year is an example of such an intensive and long drought in central Russia, which caused enormous forest fires, including ignition of peat bogs, a very rare phenomenon, and a reduction of agricultural production. NOAA has met with the Institute of Geography and Hydrometeorological Center, in Moscow, to discuss the availability of *in situ* data for validation purposes. Other activities in Russia have included a visit to the Center for the International Environmental Cooperation (INENCO), in St. Petersburg, to discuss submission of a proposal for the Cooperative Research and Development Fund (CRDF), as well as the World Climate Forum, planned for next year in Russia.

News briefs

Multinational project for Marine Synthetic Aperture Radar (SAR)

NOAA is exploring the possibility of participation in the Marine SAR Analysis and Interpretation System (MARSAIS) effort. This is a multinational project sponsored by the European Union with the goal of producing a compehensive coastal ocean monitoring and prediction system using SAR and other remote sensing data. Applications being developed as part of MARSAIS include ocean wave spectra, oil spill detection, ship detection, wind field retrieval, internal wave measurements, and surface current fronts and eddies monitoring. Actions to be pursued as a result of this meeting include writing a draft plan of action for NOAA participation in this effort.

Solar explosion sends cosmic rays to Earth

NOAA's National Geophysical Data Center (NGDC) reports that the Sun featured another magnetically-complex active region in August. The presence was felt on Earth with numerous space weather events, the most extraordinary of which was a high-energy particle release during an X-level solar flare that set off cosmic ray monitors on Earth. This is the 64th recording of a cosmic ray Ground Level Event (GLE) since records began in 1942. A 13% increase in cosmic rays was seen at the South Pole station, and 6% increases at mid-latitude stations.

DMSP nighttime images featured

Defense Meteorological Satellite Program (DMSP) nighttime images, from NOAA's National Geophysical Data Center (NGDC) of fires in Africa and heavily lit fishing boats in the Sea of Japan, were published by the New York Times on August 20. The NGDC images, produced to coincide with the start of the World Summit on Sustainable Development (WSSD), were featured under the heading "Managing Planet Earth: An Abundance of Warnings," along with satellite images from LANDSAT, NASA's Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), and NASA's Total Ozone Mapping Spectrometer (TOMS).

Cooperative effort to compile coastal seafloor characteristics

Representatives of the University of Colorado's Institute for Arctic and Alpine Research (INSTAAR), the U.S. Geological Survey (USGS), and NOAA's National Geophysical Data Center (NGDC) met June 25-26 at NGDC and INSTAAR in Boulder, Colorado to discuss cooperation on the compilation of seafloor characteristics for U.S. coastal areas. INSTAAR's Dr. Chris Jenkins authored the "dbSEABED" data mining software, which is the basis of the "usSEABED" cooperative project.

NGDC is supplying data for the project, will operate a data tracking system, and will archive data sets gathered and processed into the project. INSTAAR maintains and operates the data mining software, will process global data sets, and produce global and custom mappings. The USGS will process data from U.S. coastal areas in the "usSEABED" project and produce and distribute U.S. regional syntheses and interpretive products. The three groups are working together closely to ensure efficient production and provision of on-line and off-line data products and mappings. These data and products will have significant value for studies of benthic habitat, coastal environment, and offshore mineral resources.

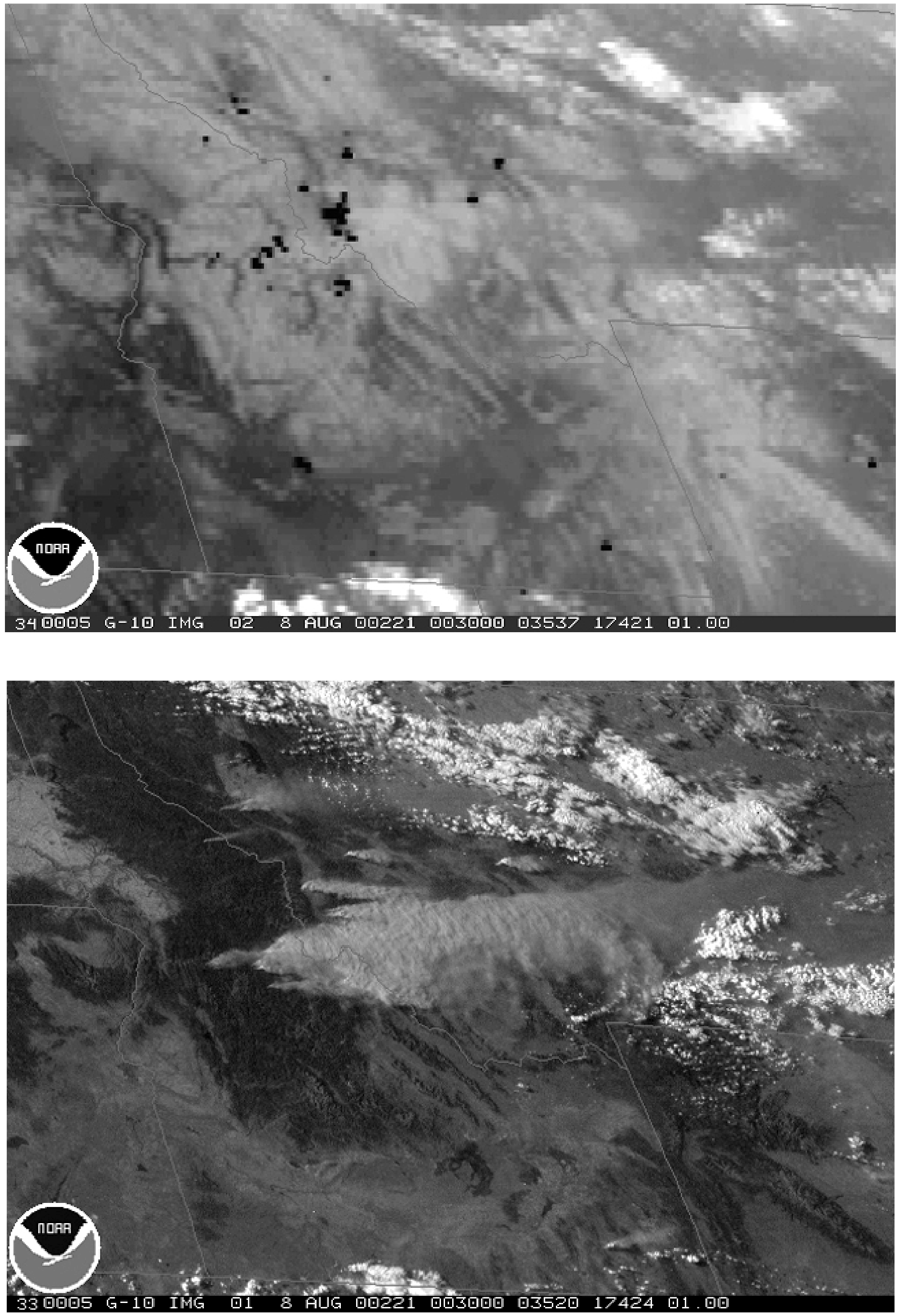
GPS services to grow at NGDC

Gordon Adams, of the National Geodetic Survey (NGS) in Silver Spring, MD, recently visited NGDC to discuss the NGS "Initiative to Sustain Uninterrupted Operation of the National Continuously Operated Stations (CORS)." These Global Positioning System (GPS) data have a large user base (~1000 requests per day), including many internal NOAA customers. Their needs included atmospheric moisture, ionospheric content and navigational parameters which are all contained in the GPS signal. The economic value for these data is estimated at $72 million. In a collaborative effort between NGDC and NOS's National Geodetic Survey, plans are proceeding on the phased implementation of an active mirror site, which is much more than a backup site — providing duplicates of all the data collection, data processing, and data distribution activities.

Fire detection program, *from page 2*
ground temperature of 300K. The two wavelengths return the same temperatures at 100% and 0% coverage of the fire within the pixel. However, a maximum temperature difference of 55K between the two channels is obtained when the fire occupies 20% of the pixel. See, e.g.: *http://www.cira.colostate.edu/ramm/goes39/tempresp.htm.*

While the high temporal frequency of the GOES satellites allows for detection of many fires, the 4 km pixel resolution limits the size and intensity of fires that can be detected. While some small, but intense fires can saturate the 4 km pixel, the fires cannot be accurately positioned within the pixel. GOES misses small fires (which may grow into quite large fires if left unchecked) that are not burning very hot compared to the surrounding ground temperature. In order to augment the GOES capabilities, NOAA's Polar Environmental Operational Satellites (POES) are also employed. They also have visible and 3.9 micron channels, both at 1.1 km resolution. The finer resolution allows for earlier detection of small fires, and shows finer location and detail of the fires. However, the imagery is available only once in 12 hours per satellite at mid latitudes. With 2 to 3 polar orbiting satellites available, these platforms provide a strategic complement to the geostationary satellites.

The primary data source used for the smoke analysis is high resolution visible imagery from the GOES spacecraft, since smoke is normally not observed in the GOES thermal bands due to the particle size. The imagery is viewed in animation, typically using hourly data. However, owing to the spectral reflectance properties of smoke particles, smoke plumes are most easily observed when there is a low sun angle (in the morning, just after sunrise and in the evening just before sunset).



▲ **Figures 2 a, b**. Fires as seen by GOES; **(a)** hotspots appear as dark spots on the 4 micron imagery, and smoke is clearly visible in **(b)** from large fires in Idaho and Montana on August 8, 2000.

The Hazard Mapping System (HMS)

The initial fire and smoke product was phased out in June 2002. To expand the product to a national level, it became necessary to rely on the computer to do some of the work. The current system, the HMS, is an interactive processing system that allows trained satellite analysts to manually integrate data from various automated fire detection algorithms with imagery from geostationary and polar orbiting satellites. The result is a quality-controlled display of the locations of fires and major smoke plumes in the 50 United States. The software was developed by government and contractor personnel using the Interactive Development Language (IDL) to build the interface. While the human eye remains critical, various automated detection algorithms have been developed which can identify hot spots in the satellite imagery. This speeds the process of searching for potential fires.

The Wildfire Automated Biomass Burning Algorithm (WF-ABBA) product was developed by Elaine Prins (NOAA/NESDIS/ORA) in collaboration with the Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin.This product, which became operational within SSD in August 2002, is the workhorse of the HMS, providing coverage over North America every half hour. The GOES WF-ABBA is an extension of the ABBA research effort primarily focused on biomass burning in S. America. It is a contextual multi-spectral (primarily 3.9 and 10.7 micron) algorithm which uses dynamic local thresholds derived from the GOES satellite imagery and ancillary databases to locate fire pixels and provides identification of fires and estimates of the sub-pixel area and mean temperature of the fires (Prins and Menzel, 1992; Prins *et al*, 1998; 2001). The ABBA website is: *http://cimss.ssec.wisc.edu/goes/burn/abba.html*.

SSD receives Moderate Resolution Imaging Spectroradiometer (MODIS) data and fire products from NOAA's MODIS Near Real Time Processing System, run by it's sister division -- the Information Processing Division. The MODIS instrument flies onboard the NASA TERRA polar orbiting satellite. The team hopes to soon have MODIS data from the recently launched AQUA satellite as well. The MODIS instrument provides 36 discrete spectral channels with resolution ranging from 1/4 to 1 km. This data source has proven to be an important asset in operational fire detection. The fire algorithm (Kaufman *et al*, 1998) was developed by the MODIS Fire and Thermal Anomalies team, Chris Justice principle investigator.

The Fire Identification, Mapping and Monitoring Algorithm (FIMMA) product is an automated algorithm to detect fires from Advanced Very High Resolution Radiometer (AVHRR) data from the NOAA polar-orbiting satellites. The FIMMA product was originally developed by Ivan Csiszar while he was a member of the Cooperative Institute for Research in the Atmosphere, working at the NOAA/NESDIS Office of Research and Applications (ORA) in Camp Springs, Maryland. The latest version of FIMMA uses geo-corrected High Resolution Picture Transmission (HRPT) AVHRR data over the US (including Alaska and Hawaii) received from the NOAA/NESDIS CoastWatch group and uses the SeaSpace Terascan software to correct for known AVHRR navigation errors. FIMMA can be run for any pass which has 3.7 micron measurements. The algorithm is described by Li (2000), modified with the addition of a slightly simpler method for nighttime fire detection. It uses AVHRR channels 2 (.9 micron), 3b (3.7 micron), 4 (10.8 micron) and 5 (12 micron). This is basically a threshold algorithm, with additional checks added in attempt to minimize false detects. This product is still considered experimental by NOAA and algorithm refinement continues.

SSD is also experimenting with the use of nighttime visible data from the Defense Meteorological Satellite Program/Operational Linescan System (DMSP/OLS). These data are received via the National Geophysical Data Center, which also provided the algorithm and interactive processing software (Chris Elvidge team leader). The satellite image is compared to an image of stable lights. Ideally, differences are due to wildfires. This process is not fully automated. Manual cloud masking and editing for false detects is required. Currently the ability to produce this product operationally, as part of the HMS suite, is under evaluation.

These automated detection algorithms, in general do a very good job of identifying potential fires, but false detects can be a problem. Think about how hot the beach can get on a summer day. A large area of heated ground can saturate the 3.9 micron sensor, making it impossible to discriminate fires that may be contained within the area. The current GOES satellites were not designed with fire detection in mind, but future GOES satellites are being designed and built to have a higher 3.9 micron saturation temperature because of this. The automated algorithms run round the clock, being initiated as soon as data are available. These data are released publicly as soon as possible, for those users who have need for immediate detects and can accept a higher rate of false detects. At 2 pm Eastern time, the fire shift begins. The analyst prepares a preliminary product as the fires begin to develop that day. This preliminary analysis may be updated as the day unfolds. Then, before the shift ends at midnight, the analyst puts out a final analysis, which will contain essentially all the major fires for that calendar day.

There are a number of limitations to the current analysis process:

- There is no way to discriminate between wildfires and control burns; one can only assume based on duration that the longer-lived hotspots are more likely to be wildfires.
- The 3.9 micron imagery can not see through clouds, other than thin cirrus. Multiple looks with different sensors throughout the day help catch fires if there are any breaks in the clouds.
- Small fires, those not burning very hot and those burning below a thick canopy of overgrowth, may go undetected. This manifests itself at times when we are able to see smoke plumes but no associated hotspot.
- Smoke is harder to detect in standard visible imagery during the middle

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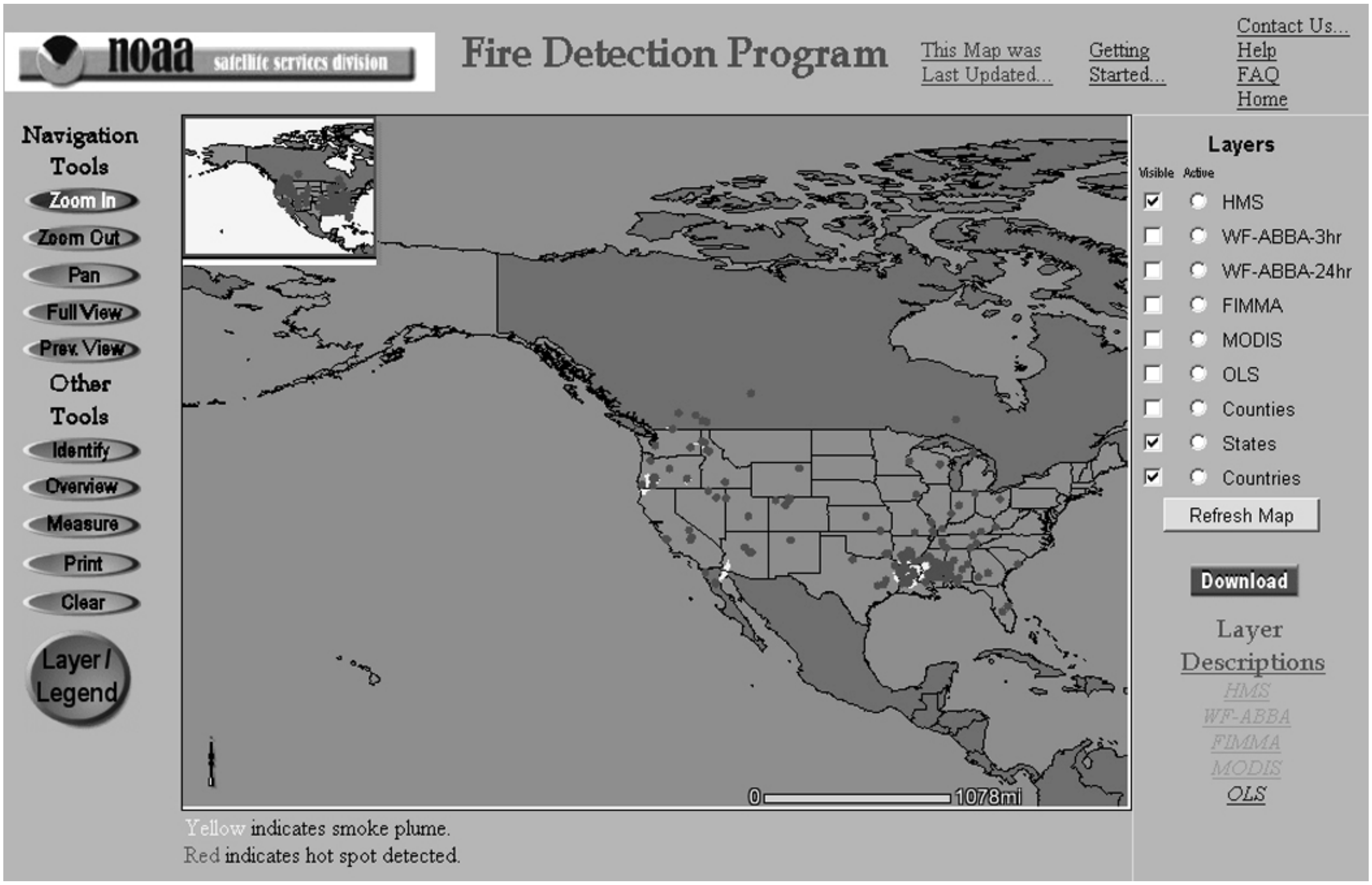

▲ **Figure 3.** The Web Geographic Information System (GIS) interface is a new way to distribute fire products to NOAA's traditional customers, as well as to reach a new set of customers, such as the land management agencies. Users can zoom down to the county level to see the fire and smoke in greater detail, can see detailed information about each detect, and can overlay other information to help with their analysis. (Site designed by Tom Callsen and Marlene Patterson)

Fire detection program, *from page 5*
of the day with a high sun angle or against a surface with a high albedo.

- Fires, especially in the western U.S., often are masked by a hot background during the afternoon in the summer. This is due to the high surface temperatures and reflectivity (due to surface soil type) which causes the GOES-10 sensor to saturate. This problem is not as acute with GOES-8 due to the higher saturation temperature (335K), versus 322K for GOES-10, of the 3.9 micron channel.

The primary data delivery mechanism for the smoke and fire product is a new Geographic Information System (GIS) webpage (Figure 3; *http://nhis7.wwb.noaa.gov/website/SSDFire/viewer.htm*, soon to be replaced with *http://www.wildfires.noaa.gov*). When users first go to the page they see the latest HMS product, but have the capability to overlay the WF-ABBA, FIMMA and MODIS fire detects. They can also zoom down to the county level to get a closer look of the fires.

Users who want to download the data can get the data directly from an anonymous file transfer protocol (FTP) site or via the web interface (Figure 4; *http://gp16.wwb.noaa.gov/FIRE/fire.html*). Data can be downloaded in ASCII text, graphic or GIS formats.

What does the future hold for the fire program? More ancillary information, such as fire scars, vegetation indices, and fire potential are likely to be available via the web-GIS fire page. Users are also interested in better access to fire imagery in geospatial formats. Future satellites and sensors [such as Visible Infrared Imager/Radiometer Suite (VIIRS), which will replace AVHRR on POES spacecraft later this decade] will have more channels and better resolution, making fire detection more reliable. As the automated algorithms improve, and the human role becomes easier, the program can extend beyong the U.S., perhaps globally.

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Rob Fennimore and Marlene Patterson (NESDIS/OSDPD/SSD/IPB), Bruce Ramsay, Elaine Prins and Chris Schmidt (NESDIS/ORA), Levin Lauritson (NESDIS/OSDPD), Tim Kasheta, Yi Song, Brian Dyke and Jason Taylor (RS Information Systems, Inc.), Tom Callsen (IMSG, Inc.), Chris Elvidge and Ruth Hobson (NGDC).

▲ **Figure 4.** The fire products can also be downloaded in a variety of formats using FTP via a web interface. (Site designed by Brian Dyke)

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NOAA's National Severe Storms Laboratory

Studying devastating storms from the heart of "tornado alley"

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The National Oceanic and Atmospheric Administration's National Severe Storms Laboratory leads the way in investigations of all aspects of severe and hazardous weather. Headquartered in Norman, Oklahoma, with staff in Colorado, Nevada, Washington, Utah and Wisconsin, the people of NSSL, in close partnership with the National Weather Service, are dedicated to improving the lead time and accuracy of severe weather warnings and forecasts in order to save lives and reduce property damage.

Severe weather research conducted at NSSL has led to substantial improvements in severe and hazardous weather forecasting, resulting in increased warning lead times to the public. NSSL scientists are exploring new ways to improve our understanding of the causes of severe weather, and ways to use weather information to assist National Weather Service forecasters, as well as federal, university and private sector partners.

Recent accomplishments

In the past few years, scientists from NSSL have completed several field experiments. During spring and summer 2002, meteorological researchers from around the world gathered in Norman and the Oklahoma panhandle to track the nearly invisible swaths of moisture that fuel severe thunderstorms and heavy rain across the southern Great Plains from Texas to Kansas. NSSL researchers led an armada of 30 weather-tech vehicles that measured temperature, humidity, wind and other variables in the lower atmosphere. Scientists hope the data they gathered will be the key to better predictions of when and where thunderstorms will form and how intense they will be.

Two additional experiments studied severe and hazardous weather. IPEX, the Intermountain Precipitation Experiment, was designed to improve forecasts of winter weather, especially in the high population growth areas of the western United States. STEPS, the Severe Thunderstorm Electrification and Precipitation Study, focused a number of data gathering tools on thunderstorms in the high plains to better understand how rain and lightning are formed. The knowledge gained through these field programs will lead to better forecasts of deadly weather phenomenon including tornadoes, lightning, hail, flash floods, heavy snow, ice and freezing rain.

NSSL continues to be a pioneer in the development of weather radar. The lab is presently researching the use of dual polarization radar to improve precipitation measurements and hail identification. This proposed upgrade to the current NEXRAD Doppler radar hardware will provide more information about precipitation in clouds to better distinguish between rain, ice, hail and mixtures. Such information will help forecasters provide better warnings for flash floods, the number one severe weather threat to human life.

NSSL is committed to incorporating cutting-edge scientific understanding of severe weather signatures in radar data into tools designed to help National Weather Service forecasters make better and faster warning decisions. The latest tool, NSSL's Warning Decision Support System II, includes automated algorithm detection tools for the NEXRAD Doppler radar to iden-

tify rotation in storms preceding tornadoes, likelihood and size of hail, as well as simply identifying and tracking storms. This information is presented in an easy-to-use display including tables, graphs and data interrogation tools. Several of these tools have already been integrated into the National Weather Service's systems and have contributed to improved warning lead times with fewer false alarms.

What's next for NSSL?

Phased array radar

NSSL researchers will soon begin adapting state-of-the-art radar technology currently deployed on Navy ships for use in spotting severe weather. Phased array radar reduces the scan or data collection time from five or six minutes to only one minute, potentially extending the average lead time for tornado warnings well beyond the current average of 11 minutes. When combined with other technology being developed at NSSL, warning lead times may be extended even farther.

Significant work is required to adapt current phased array radar military technology to civilian use for weather applications. This process has proven successful before, when NSSL researchers took surplus military Doppler radar components and developed what became the WSR88D radar. The deployment of a system of NEXRAD radars across the United States was a cornerstone of the modernization of the National Weather Service. Most importantly, it has helped forecasters provide better forecasts and warnings, saving countless lives.

The phased array radar project will begin a new era in NSSL's leadership in the research and development of future generations of weather radar. However, the NSSL is not working alone. All aspects of the initiative will be carried out in a partnership among several federal,

private, state and academic partners, including NOAA's Forecast Systems Laboratory and National Weather Service, U.S. Navy, Federal Aviation Administration, Lockheed Martin and the University of Oklahoma.

National Weather Center

NSSL has a unique opportunity to combine facilities with the National Weather Service and several key university weather organizations also focused on severe weather research. Planning is underway for the proposed National Weather Center, a new $60 million facility that will become the premier severe weather research and forecasting complex in the world. The new building will increase collaboration and communication for the weather researchers and forecasters engaged in complimentary efforts toward better forecasts and warnings of severe and hazardous weather.

Improving the state of the science

NSSL has also begun working on ways to improve short-term weather forecasting computer models for the National Weather Service, basic tornado research to understand how tornadoes form, and real-time delivery of radar data to the meteorological community and interested partners. In addition, NSSL researchers continue to strive for an improved understanding of tornadoes and other severe weather by creating new tools such as mobile Doppler radars employing the latest technologies and by deploying radio controlled aircraft carrying weather instruments into and around storms.

Research partnerships

NSSL has a research partnership with the Cooperative Institute for Mesoscale Meteorological Studies (CIMMS), a cooperative institute between NOAA and the University of Oklahoma. Additionally, NSSL conducts collaborative research with the U.S. Navy, Air Force, Department of Transportation, Federal Aviation Administration, and several large and small corporations. NSSL is a $15 million laboratory ($6 million in NOAA base), that supports approximately 50 federal employees and 92 university employees. ■

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Partnerships, knowledge, innovation and leadership

Challenges of integrated data systems

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The NOAA Program Review recommends that NOAA carry out future missions "innovatively in partnership with other nations, other Federal, state and local agencies, the private sector and academia". It also recommends establishing and improving many cross-agency and cross-line office initiatives and relationships (NOAA Program Review Team, 2002). These recommendations make it clear that partnerships are going to play an important role in the new NOAA on many levels.

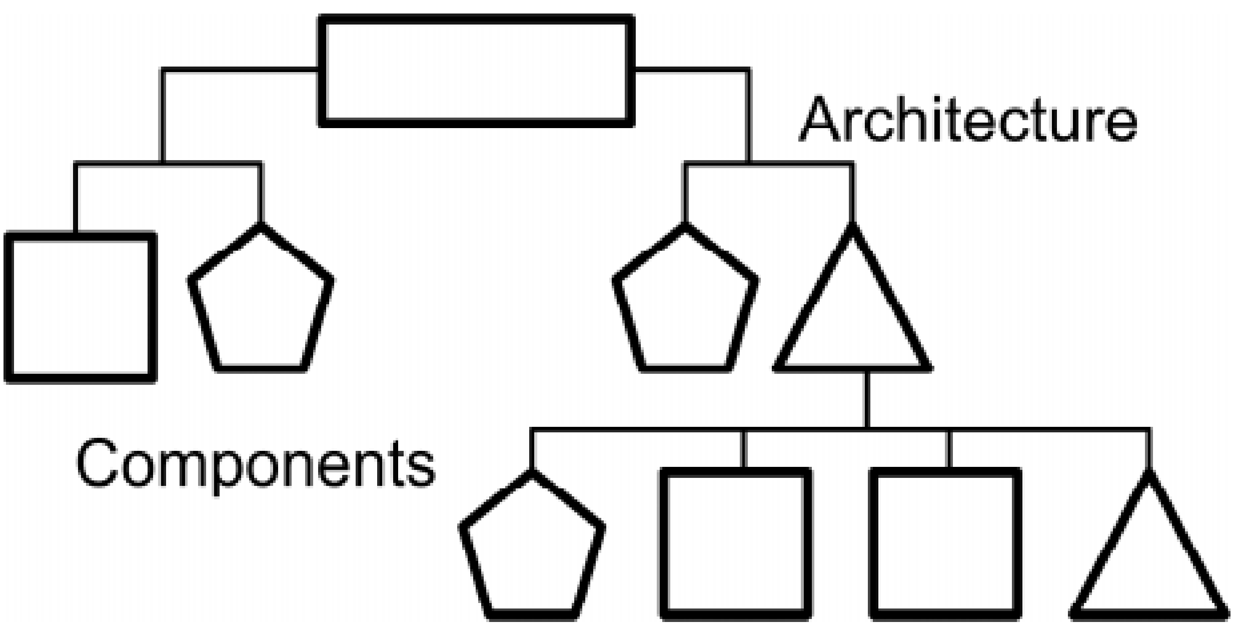
Many aspects of partnerships combine to make their management much more difficult than management of the relatively simple projects that we spend most of our time on. The situation is further complicated by the fact that achieving the goals of the Program Review requires considerable innovation. Understanding innovation and managing projects that depend on it for success present significant challenges that once again are outside of our general experience.

All of these factors indicate that understanding innovation is on the critical path to success for the new NOAA. Fortunately, there is a rich literature on this topic. This literature includes discussions of many types of innovation and approaches to managing them. The differentiation between component and architectural innovation described by Henderson and Clark (1990) seems very relevant to NOAA as does the discussion of sustaining and disruptive innovation by Christensen (1997). This paper outlines those concepts and speculates about their relationship to NOAA with the hope of initiating a dialog and maybe helping create successful partnerships.

Data systems and knowledge or innovation types

Data systems are made up of components and connections between them, (architecture in Figure 1). It is clear that developing successful systems requires knowledge about the components, termed "component knowledge", and knowledge about the connections, termed "architectural knowledge". Henderson and Clark (1990) point out that these types of knowledge are developed and managed quite differently in most organizations. Component knowledge is generally resident in individuals or groups. There are many such experts, or "gurus" in any software environment. In many cases they are the principal developers of a particular component and they are the people that others seek out when problems occur with that particular component.

Understanding how components are connected is architectural knowledge. Architectural knowledge is increasingly important as we build systems by connecting objects and class libraries, as in object oriented programming approaches, or commercial off-the-shelf (COTS) tools. It develops quite differently than component knowledge. In systems where the architecture is



▲ **Figure 1.** Data systems are made up of components connected by architecture. Note the similarity to an organizational chart.

stable, this knowledge tends to become embedded in the practices and procedures of the organization and even in the structure of the organization itself. Note the similarity of Figure 1 to an organizational chart. One could easily associate groups of components with groups of people and the architecture with the organizational structure. Organizations build knowledge and capability around recurrent tasks. Architectures of those tasks that work well become part of standard operating procedure. The architecture becomes embedded in the "the way we've always done it" and practices are based on tradition rather than knowledge about why those traditions came to exist in the first place.

In NOAA, many legacy systems have been described as "stovepipes" because of the difficulties experienced when one attempts to add new data or capabilities to them. In these cases, architectural knowledge is tied up in the same experts that hold component knowledge. In fact, the components and the connections may not be defined anywhere except in the code. Incomplete documentation can many times exacerbate the problems associated with distributing that knowledge through the enterprise.

Extending these concepts from knowledge to innovation is straightforward. Component innovation (or incremental innovation) involves improvements made to the components of the system. This is illustrated in Figure 2 by the components increasing in size and changing color. Improving the performance of a particular software tool (i.e. a satellite data reader) is a component innovation as is evolving code so that it functions in a new operating system. Improving the functionality of existing large systems that must work together might even be considered component innovation in the context of a new NOAA. These innovations are the stuff of the everyday experiences of many developers and managers. We understand the concept of component innovation because we do it everyday.

Architectural innovation involves connecting existing components in new ways (Figure 2). The core design concept behind each component – and the associated scientific and engineering knowledge – remains the same, although a small amount of component innovation may be required to make the new connections work. Add-

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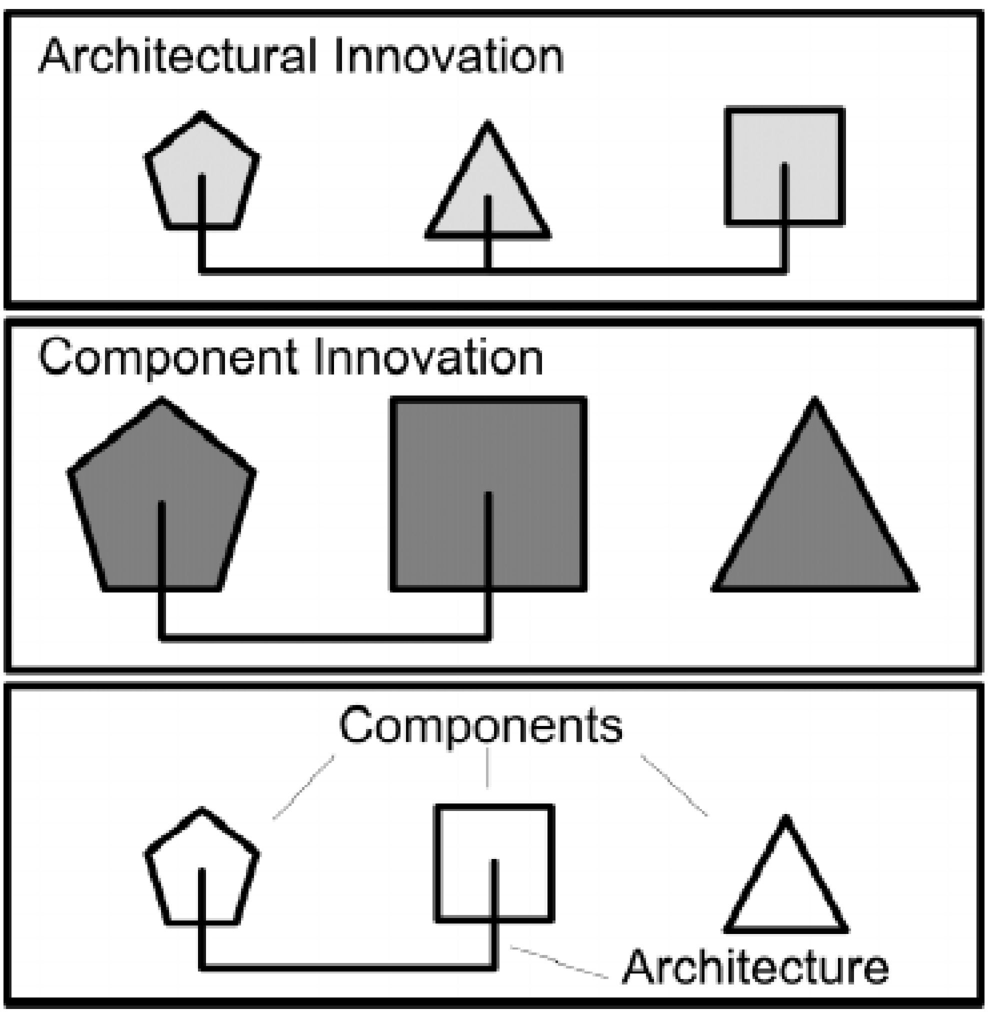

▲ **Figure 2.** Types of innovation.

Partnerships, *from page 11*

ing the capability to read a new data format to an existing software tool is an architectural innovation. It creates a new connection between existing code and existing data. Modifying a web visualization tool to support multiple back-end data access systems is another architectural change.

It is important to note that components that can function well in multiple architectures are different than those that work in stovepipes. The internal workings of architectural components are generally hidden from view and the external interfaces must be well documented and tested. In many cases those interfaces are implemented using standards such as XML in order to simplify the programming and documentation process.

Architectural innovation and organizational change

A recurring "mantra" of many partnership projects is that they will not reinvent anything; instead "best of breed" components will be identified and combined in new ways. This mantra clearly identifies such partnerships as architectural innovation. In fact, if the mantra were strictly followed, innovations related to many of these projects would be completely architectural. This may have profound implications for the management of these projects and for their eventual success or failure. Henderson and Clark (1990) describe the difficulties of architectural innovation in established firms:

> An established organization setting out to build new architectural knowledge must change its orientation from one of refinement within a stable architecture to one of active search for new solutions within a constantly changing context. As long as the dominant design remains stable, an organization can segment and specialize its knowledge and rely on standard operating procedures to design and develop products. Architectural innovation, in contrast, places a

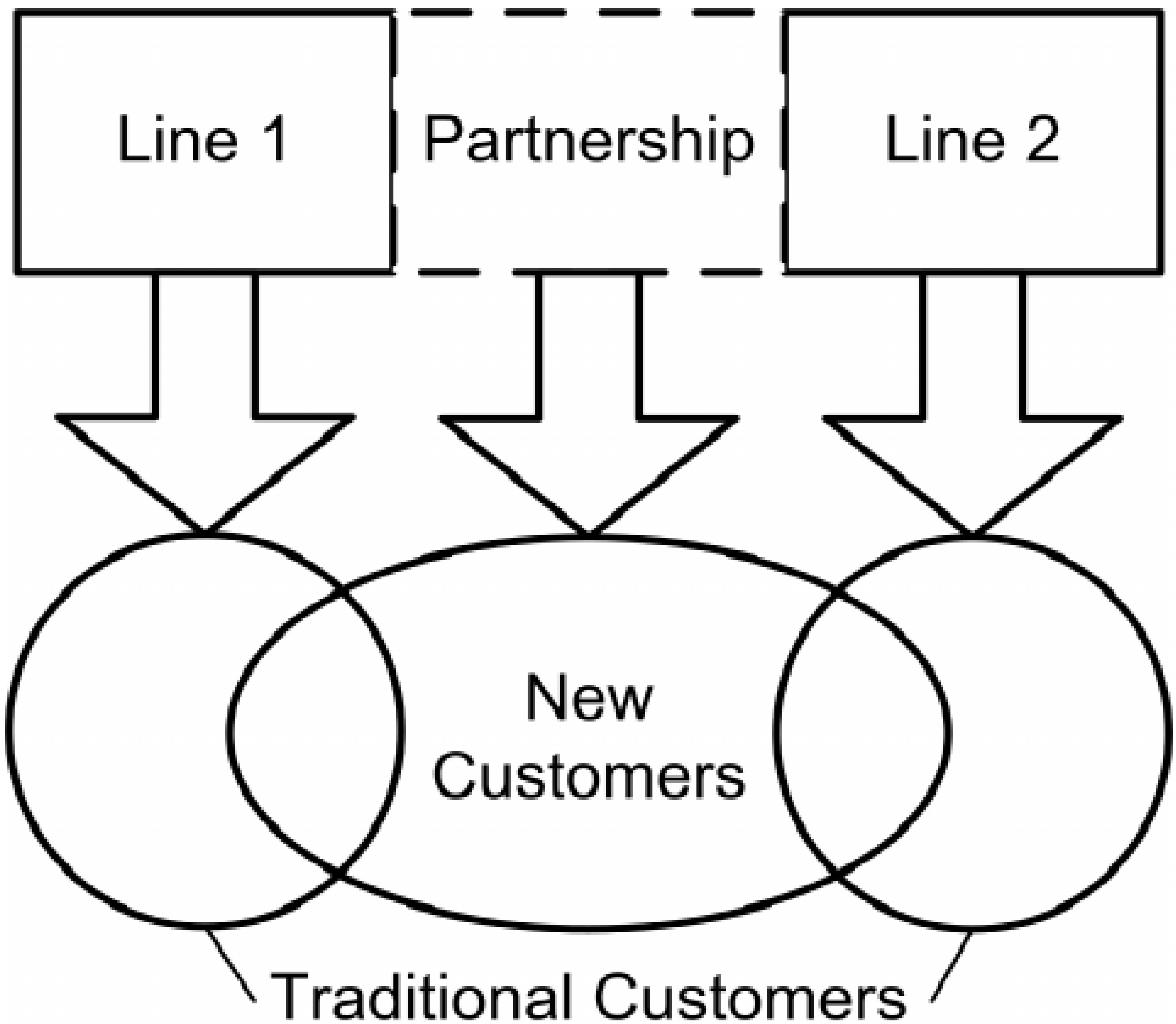

Figure 3. Partnerships and customers.

premium on exploration in design and the assimilation of new knowledge. Many organizations encounter difficulties in their attempts to make this type of transition. New entrants, with smaller commitments to older ways of learning about the environment and organizing their knowledge, often find it easier to build the organizational flexibility that abandoning old architectural knowledge and building new requires.

Christensen (1997) describes sustaining and disruptive innovations. His concepts are similar to, but not synonymous with Henderson and Clark's. In Christensen's case the critical differentiator is the customer that the innovation serves. Sustaining innovation is aimed at improving products for traditional customers (outside arrows in Figure 3), whereas disruptive innovations target unknown (and many time unknowable) customers. Component innovation tends to be sustaining and architectural innovation may be disruptive. The World Wide Web and new partnerships both bring new customers to established NOAA programs (Figure 3). These are, therefore, disruptive innovations.

The challenge in managing these disruptive innovations is intimately related to the infusion of new customers. Employees many times have long-term relationships with their existing internal and external customers and the perceived needs of those customers drive their everyday work decisions. Convincing a work force to make decisions that serve the needs of new and potentially unknown customers is a difficult management and leadership challenge.

Christensen's discussion of organizational capabilities and disabilities becomes relevant here. Organizational capabilities are different than the capabilities of individuals within the organization. Moreover, an organizational capability to do one thing can become a disability to do another. These capabilities are determined by resources, processes, and values. Resources, i.e. people, hardware, and time, are the most visible factors contributing to capabilities. Processes are the patterns of interaction, coordination, communication, and decision-making through which organizations accomplish tasks and create value. Values are the criteria by which decisions about priorities are made at all levels in the organization. Having the organizational capability to accomplish goals depends on all three of these factors:

> Managers who face the need to change or innovate, therefore, need to do more than assign the right resources to the problem. They need to be sure that the organization in which those resources will be working is itself capable of succeeding, and in making that assessment, managers must scrutinize whether the organization's processes and values fit the problem... When the organizations capabilities reside primarily in its people, changing to address new problems is relatively simple. But when the capabilities have come to reside in processes and values and *especially* when they have become embedded in culture, change can become extraordinarily difficult.

The "embedding" that Christensen describes is very similar to the development of architectural knowledge in the Henderson and Clark model. Regardless of what you call them, both of these processes contribute significantly to making architectural or disruptive innovation so difficult.

This interpretation clearly suggests that architectural innovation involves a much more significant element of organizational change than component innovation. Many experts suggest that organizational change requires more leadership than management (Kotter, 1990). In this context that suggests that successful architectural innovation requires more leadership and that component innovation requires more management. It also suggests that architectural innovation requires a significantly different approach to organizational learning than component innovation.

Management and leadership

Management and leadership are many times discussed together and many times thought to coexist in upper levels of organizations; however, considerable insight may be gained by differentiating between them. Kotter (1990) discusses the differences between management and leadership in some detail:

> Leadership is different than management, but not for the reasons most people think. Leadership isn't mystical or mysterious. It has nothing to do with having "charisma" or other exotic personality traits. It is not the province of a chosen few. Nor is leadership better than management or a replacement for it. Rather, leadership and manage ment are two distinctive and complementary systems of action. Each has its own function and characteristic activities. Both are necessary for success in an increasingly complex and volatile business environment.
>
> Management is about coping with complexity… Without good management, complex enterprises tend to become chaotic in ways that threaten their very existence. Good management brings a degree of order and consistency to key dimensions like quality and profitability of products. Leadership, by contrast, is about coping with change…Major changes are more and more necessary to survive and compete effectively in this new environment. More change always demands more leadership.
>
> These different functions – coping with complexity and coping with change – shape the characteristic activities of management and leadership. Each system of action in volves deciding what needs to be done, creating networks of people and relationships that can accomplish an agenda, and then trying to ensure that those people actually do the job. But each accomplishes these tasks in different ways.

— continued on page 16

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The Coral Reef Information System Web site (CoRIS) is being officially released at *http://www.coris.noaa.gov/* as of October 1, 2002. Designed to provide the public with a single point of access for coral reef data and information derived from NOAA programs and projects, CoRIS supports NOAA's activities on the National Coral Reef Force and NOAA's implementation of the National Action Plan to Conserve Coral Reefs.

Corals are extremely ancient animals that date back 400 million years, and over the last 25 million years they have evolved into modern reef-building forms. Coral reefs are one of the most diverse habitats in the world and are considered the largest structures on earth of biological origin that rival old growth forests in their longevity. Reefs can be many hundreds of years old. Home and nursery for almost a million fish and other species, reefs also provide important protection for coastal communities from storms, wave damage and erosion.

The CoRIS site is organized into a series of sections, with "Discover NOAA's Data" being the centerpiece of the site. Here, CoRIS provides users with two different ways to access some 19,000 aerial photos, 400 preview navigational charts, tide stations, paleoclimatological studies, photo mosaics, coral reef monitoring, bleaching reports, and more information. The first is Map Search which uses an application of ArcIMS that results in direct access to many products. This search engine is ideal for users who have an idea of what they are looking for or desire a specific geographic area. There is also a Text Search engine that allows easy examination of metadata records, which are detailed summaries of the actual data. This method is very effective for users who want to learn more about the data, or have questions about specific data offerings.

Another section, "About Coral Reefs," offers four essays that discuss some of the more important aspects of coral reefs: "What are Coral Reefs," an essay on the general description of the individual coral animal, "Coral Reef Biology," which presents an overview of the major reproductive, feeding, and competitive behaviors in many species of corals, "Major Reef-building Coral Diseases," providing a summary of coral diseases, many of which have increased in frequency in the last 10 years, and "Hazards to Coral Reefs," an overview of natural and anthropogenic factors threatening many reef systems.

Other sections include:

- "Professional Exchanges" that present summaries of selected topical discussions among experts that first appeared on NOAA's Coral Health and Monitoring Program (CHAMP) listserve.
- The Library provides a series of collections, publications, Web sites and organizations that focus on NOAA materials and activities as well as selected materials to NOAA.
- NOAA's Activities briefly describes NOAA's efforts thus far to fulfill the goals of the National Action Plan to Conserve Coral Reefs, which was issued by the U.S. Coral Reef Task Force in March 2000.
- The Glossary furnishes definitions for hundreds of terms associated with coral reef science and conservation.

This site is managed by the National Oceanic and Atmospheric Administration, U.S. Department of Commerce. Materials posted on this site are reviewed by professional staff prior to publishing. All material on the site, including the multimedia gallery, resides in the public domain and can be freely distributed. The CoRIS team is responsible for all text, images, and search engines on this site.

Among the NOAA offices and labs involved with the development of CoRIS are the National Oceanographic Data Center, the National Ocean Service, NOAA Central Library, the Atlantic Oceanographic and Meteorological Laboratory, the Paleoclimatology Program at the National Geophysical and National Climatic Data Centers, the Office of Oceanic and Atmospheric Research, and the National Marine Fisheries Service.

Prior to CoRIS, a seeker of NOAA coral reef information faced a confusing array of over 50 NOAA coral reef web sites. CoRIS, backed by powerful search engines, offers a web-enabled, GIS-enhanced, state-of-the-art information system utilizing a single web portal to gain easy access to NOAA's coral reef resources. By cataloging and indexing metadata summarizing the actual data holdings, CoRIS easily guides the user to the desired data and information.

Corals are now a cross-cutting theme throughout NOAA, and the recent "National Action Plan to Conserve Coral Reefs" calls on NOAA and its Coral Reef Task Force partners to reduce or eliminate the most destructive human-derived threats to coral reefs. The plan describes nine long-range, far-reaching strategies to address these threats:

- Expand and strengthen the network of coral reef marine protected areas (MPAs) and reserves;
- Reduce the adverse impacts of extractive uses such as overfishing;
- Reduce habitat destruction;
- Reduce pollution such as marine debris;
- Restore damaged reefs;
- Reduce global threats to reefs;
- Reduce impacts of international trade of coral reef resources;
- Improve interagency accountability and coordination; and
- Create an informed public.

For more information contact:
Doug Hamilton (NOAA/NESDIS/NODC) at dhamilton@nodc.noaa.gov.

Moored Upward Looking Sonar (ULS) for sea ice volume estimates

Moored ULS data provide information on sea ice draft from which both ice thickness and volume can be inferred. Recent studies using submarine ULS data distributed by the National Snow and Ice Data Center (NSIDC) suggest that arctic ice is thinning; see *http://nsidc.org/data/g01360.html*.

The World Climate Research Programme's Arctic Climate System Study (Climate and Cryosphere Project) hosted a meeting in Tromso, Norway, in early July, to coordinate processing and archival of data from moored instruments that complement submarine data. About 65 buoy years of data from Australian, Canadian, German, and U.S. research groups will be documented and distributed by NOAA under the direction of NSIDC.
Contact: NGDC

Global Land Ice Measurements from Space (GLIMS)

In July representatives of the USGS/Flagstaff GLIMS Coordination Center met with NSIDC members of the GLIMS team in Boulder. Discussions included the format of the NASA-funded NSIDC GLIMS glacier data base, techniques for automatically analyzing glaciers in satellite imagery, and aspects of incorporating older glacier data sets into the new framework. There are estimated to be some 160,000 glaciers worldwide; 70,000 of these are represented in the NOAA-funded World Glacier Inventory (*http://nsidc.org/data/g01130.html*). The GLIMS project and some 20 regional centers around the world are aiming to document the current state of the world's land ice. More information on the GLIMS project is at *http://www.glims.org/*.
Contact: NGDC

Congressional office uses wind data for transportation issue

The office of Massachusetts Congressman Michael Capuano requested two years of daily average wind speed and direction data along with wind gust information. These files, which involved a dispute involving the Boston-Logan airport runway and wind speed frequency, were transferred electronically in PDF format within hours of the request.
Contact: NCDC

Data products and services

First AIRS data distributed to NWP centers

NOAA's NESDIS (National Environmental Satellite and Data Information Service) has processed and released a single day of AIRS (Atmospheric InfraRed Sounder) radiances to the NWP (Numerical Weather Prediction) community in the U.S. and Europe for evaluation. AIRS is the first of a new generation of hyperspectral infrared sounders and will significantly improve the accuracy of satellite-derived atmospheric temperature and moisture soundings.

Data from AIRS is expected to extend the current range of reliable medium-term forecasts by several hours. Regular distribution of calibrated AIRS radiance data will begin after the AIRS calibration team has completed its evaluation. AIRS was launched on NASA's Aqua satellite on May 4.
Contact: ESDIM

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New data on tree growth/climate relationships

The NOAA Paleontology Program has archived new Alaskan tree-ring data used by Lloyd and Fastie (2002) to analyze climate-growth relationships in the Boreal forest. The research indicates that tree growth in the Boreal forest of Alaska has declined over the past 50 years, despite the strong warming trend observed over this time interval. The authors propose that drought stress on trees is increasingly becoming a factor limiting tree growth in the rapidly warming Boreal forest zones. The data and research summary can be obtained on the NOAA Paleoclimatology Program website at: *http://www.ngdc.noaa.gov/paleo/pubs/lloyd2002/lloyd2002.html*.
Contact: NCDC

Ice core atmospheric methane data archived

The NOAA Paleoclimatology Program has archived high-resolution methane (CH4) data from the Law Dome, Antarctica ice core. Published by Etheridge et al. in the Journal of Geophysical Research (1998), the data documents an approximately 150% incrrease in atmospheric methane since 1750. Methane is the second most important human-influenced greenhouse gas after carbon dioxide, and these data were included in the Intergovernmental Panel on Climate Change (IPCC) 2001 report. The data arre available at: *http://www.ngdc.noaa.gov/paleo/icecore/antarctica/law/law.html*.
Contact: NGDC

Digital side-scan sonar data

NGDC has received a second shipment of raw digital side-scan sonar data from the National Ocean Service (NOS). The first shipment is being archived and reviewed with SonarWeb Pro to visually inspect the data. The data are approximately 190 gigabytes of sea floor imagery obtained during NOAA Ship *Whiting*'s hydrographic survey operations on projects in Virginia, Georgia, and Puerto Rico. The second shipment contains sea floor imagery acquired during NOAA Ship *Rude*'s hydrographic survey operations in Delaware and Chesapeake Bays. An archive is being established for these data, including the creation of access and retrieval capabilities.
Contact: NGDC

Partnerships, *from page 13*

He goes on to describe the different actions that characterize leadership and management:

Leadership	Management
Setting a direction	Planning and budgeting
Aligning people	Organizing and staffing
Motivating people	Controlling and problem solving

Organizational Values	Organizational Processes	Organizational Resources

These differences can also be translated into the organizational capabilities model, with resources at the management end, values at the leadership end and processes in the middle. Christensen would agree with Kotter that projects can not be successful without an effective combination of all these things, without a combination of management and leadership.

Conclusion

The NOAA Program Review highlights the critical role of internal and external partnerships in the "new NOAA." These partnerships will involve connecting existing systems in new ways and reaching out to new customers. These are well-known characteristics of architectural and disruptive innovation. Achieving such innovations is likely to require significant elements of organizational change; in fact, it is likely that these partnerships must be addressed primarily as organizational change efforts if they are to be successful.

How might this be done? Several ideas emerge from this discussion. First, partnership plans must 1) consider how leadership and management can coordinate to accomplish goals, and 2) specifically address processes and values along with resources. The leaders must be certain that the partnership values are clear to all participants. The partnership must be sold on the basis of those values, so they must be explained using many communication channels and demonstrated continually by consistent actions. It is critical that all layers of management understand those values so that their decisions and actions are consistent with them.

Second, leaders must identify staff that share the partnership values and are already making decisions consistent with them. These people must be supported with resources and visibility and they must be recruited to develop new processes that support the partnership. More importantly, the leaders must identify mid-level managers and staff whose decisions and actions are not supporting the partnership values. Their points of view must be understood and dealt with before they undermine the partnership.

Making new partnerships work is challenging in any established organization. Hopefully, the ideas discussed here will contribute to understanding some of the challenges and achieving success.

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