Evolution of the U.S. Meteorological Satellite Program Some Reminiscences

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Preamble

I am very pleased to have been invited to give the 1994 lecture in honor of my good friend Vern Suomi. We first met in 1956, after I joined the U.S. Weather bureau in Washington, D.C., when I was interested in developing boundary-layer instruments for use in the Bureau and sought Vern's advice and help. A few years later, we both became involved in the application of satellites to meteorology. I owe him a great deal for his advice, enthusiasm, wisdom, and his friendly impatience over the years. (Thank you Vern).

Early history of the satellite program

A classified study by Stan Greenfield and Will Kellogg (1951) with a contribution by J. Bjerknes speculated on the possibility of using an earth-orbiting satellite by showing how meteorological analyses could be improved by the use of high-altitude cloud pictures, in this case obtained from rockets. Other studies in the 1950s, such as one by Les Hubert and Otto Berg also using rocket pictures of clouds, as well as others by Harry Wexler and Sig Fritz, and by Arnold Glazer and John Conover, demonstrated improvements in synoptic analyses that could be achieved by using cloud images from space. However, these early studies did not anticipate the scope of today's satellite observations.

On 29 July 1955, the White House announced plans to develop satellites as a U.S. contribution to the International Geophysical Year. This became the ill-fated Vanguard program under the aegis of the navy, noted for the failure of its launch vehicles. The program included two meteorological experiments, one of which was being developed by Vern Suomi to measure the planetary radiation balance.

On 4 October 1957 the nation was galvanized by the launch of *Sputnik I* by the former Soviet Union. The ill-fated Vanguard program was not enough to satisfy the public and political demand for a response to the Soviet Union's achievement.

The Advanced Research Projects Agency (ARPA) was established in the Department of Defense in April 1958 to pursue deserving satellite projects. Where good ideas were available, they were funded. Based on the studies earlier in the decade, ARPA funded the TIROS meteorological satellite project and established an oversight committee chaired by Will Kellogg to advise on its development. [Fritz and I represented the U.S. Weather Bureau and Ed Cortwright represented the National Advisory Committee on Aeronautics, soon to become the National Aeronautics and Space Administration (NASA).] TIROS was designed and built by the Radio Corporation of America under the technical supervision of the U.S. Army Signal Corps. Bill Stroud, Rudi Stampfl, Rudi Hanel, Bill Nordberg, Herb Butler, Bill Bandeen, and others in the TIROS group at the Signal Corps later were transferred with the TIROS program to the Goddard Space Flight Center of NASA.

The first successful meteorological satellite experiment was on *Explorer-7*, launched in 1959. Vern Suomi and his experiment to measure the planetary heat balance had "jumped ship" from the navy's Vanguard program and landed on a successful army launch vehicle.

NASA opened its doors 1 October 1958 and things really started moving fast. Multimillion dollar decisions were made in a matter of days. NASA funded the U.S. Weather Bureau to establish the Meteorological Satellite Section in the Office of Research, later to be-

[1]Public Papers of the Presidents of the United States: John F. Kennedy, 1961–63, 1962–64. Government Printing office, 404.

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come the National Environmental Satellite Service (NESS) in the National Oceanic and Atmospheric Administration (NOAA).

President Eisenhower transferred the TIROS program from the Department of Defense to NASA in early 1959. *TIROS-1* was launched on 1 April 1960—just two years after the project started in ARPA. The TIROS success and the times led President Kennedy, in his famous speech before Congress in 1961,[1] to call upon the United States to land a man on the moon before the end of the decade and also to request the Congress "to provide . . . an additional 75 million dollars, of which 53 million dollars is for the Weather Bureau, [that] will help give us at the earliest possible time a satellite system for world-wide weather observation." Thus, the Weather Bureau received a mandate to establish the operational weather satellite system launched in 1966. (It is interesting to note that the addition of these funds for the satellites more than doubled the Weather Bureau's budget at the time.)

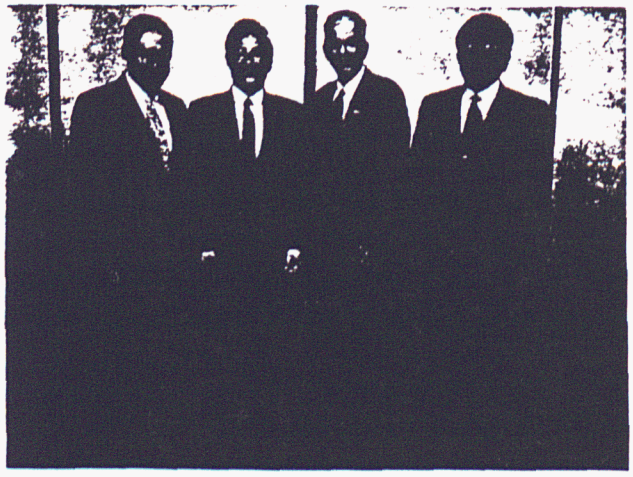
The early history of the meteorological satellite program leads me to the first point I would like to make:

- Support for major and costly new projects comes from being ready to take advantage of an external event or force that garners the necessary political and public support.

Importance of individual contributions in a team effort

Big projects, such as development and operation of satellites, require big team efforts, but individual contributions that stand out are essential to substantial progress and unique advancements. I will give four examples from many in the history of the meteorological satellite program, the first two of which are only known by a few people.

1) The optic axes of the camera on *TIROS-1* were parallel with the spin axis of the spacecraft. Before launch, it was expected that the orientation of the spin axis could be predicted using the dynamics of a gyroscope moving in the predicted orbit of the spacecraft. After launch, the optic axes wandered all over in an unpredictable manner. Cloud physicist Sean Twomey, then working in the Meteorological Satellite Section of the Weather Bureau, postulated that electrical currents flowing through the wiring of the satellite were interacting with the earth's magnetic field to cause the spacecraft to deviate from its predicted attitude. He then used records of the actual programming of the satellite (which determined the variable electrical currents) and the geographic location of the pictures obtained to develop a predictive capability for picture location. This discovery led to the subsequent use of electrical coils in spacecraft to intentionally steer them.
2) Coverage of the early TIROS was limited by the optic axis orientation. Tom Haig, known to many of you at the University of Wisconsin, while manager of a precursor to the Defense Meteorological Satellite Program in the Department of Defense, proposed and implemented a scheme whereby the optic axes of the cameras were perpendicular to the spin axis of the satellite that, in turn, was kept oriented perpendicular to the orbit plane. The camera shutters were triggered when the cameras were pointing normal to the earth's surface beneath. This technique was also introduced by NASA on TIROS and continued in the series of operational Environmental Survey Satellites operated by the Environmental Science Services Administration, which had absorbed the former U.S. Weather Bureau and its Meteorological Satellite Section.
3) Lou Kaplan (1959) proposed a scheme to obtain atmospheric soundings from space by infrared spectrometry. A group in the Weather Bureau's Meteorological Satellite Section, led by Dave Wark and Don Hilleary, developed the Satellite Infrared Spectrometer launched in 1969 on *Nimbus-3* that produced the first such soundings. Bill Smith, who had joined the group, called the National Environment Satellite Center, in 1969, devised the first operational retrieval technique to produce soundings. With Rudi Hanel of the Goddard Space Flight Center, Hilleary, Kaplan, and Wark received in 1970 the first American Meteorological Society Second Half Century Award (now the Charney



Elbert. W. (Joe) Friday, director of the NWS and U. S. permant representative to the WMO, Zou Jingmeng, WMO president, Verner Suomi, and G. O. P. Obasi, WMO secretary-general at the IMO Prize award ceremony.

Award), and Smith was presented with the Meisinger Award.

4) In 1964 Vern Suomi proposed flying his Spin-Scan Cloud Camera on NASA's first Applications Technology Satellite (*ATS-1*), an experimental geostationary satellite, to estimate upper-air winds from measurements of cloud movements in a time sequence of pictures. Suomi's working model of the camera, his experiment logic, and powers of persuasion convinced Homer Newell, then associate administrator of NASA, to take the risk and fly the camera, which was launched just two years later in 1966. The rest is history and has evolved into the international network of geostationary satellites of today. [Suomi later developed the concept of sounding the atmosphere from geostationary orbit now used on NOAA's Geostationary Operational Environmental Satellites (GOES).] For his pivotal development, the AMS awarded Suomi with its highest award, the Rossby Medal, in 1968, while Newell received the AMS Cleveland Abbe Award in 1972 for his key decisions.

These examples demonstrate my second point:

- While outstanding team efforts are needed in big and complex programs, it is essential to foster the individual contributions that lead to significant progress. It is up to management to provide the atmosphere that attracts and encourages such contributions, and management must be prepared to risk trying out new ideas of merit.

Program growth in the decade of 1970

Meteorological satellite programs flourished in the decade of 1970 and their momentum carried into the 1980s. NASA and NOAA forged an effective partnership for both research and development and operations. I would like to mention four examples.

1) NASA's *Synchronous Meteorological Satellites (SMS) 1 and 2*, the first of which was launched in support of the Global Atmospheric Research Program's Atlantic Tropical Experiment in 1974, were the prototypes of the first design of NOAA's GOES satellites, the last of which is still in operation. Suomi's sounding capability was added on *GOES-4* in 1980. The Geostationary Meteorological Satellites of Japan also are based on the SMS/GOES design. *GOES-8*, launched 13 April 1994, is the first geostationary spacecraft of a new design.
2) The Nimbus program of NASA supported the development and demonstrated the efficacy of new components for operational use on NOAA's polar-orbiting satellites, including the first atmospheric sounder, but the Nimbus program ended after seven successful spacecraft.
3) NASA developed and launched in 1979, just in time for the Global Weather Experiment, the prototype of the current series of NOAA polar-orbiting operational satellites.
4) NASA developed and flew the Earth Radiation Budget Experiment (ERBE) and NOAA flew ERBE sensors on its operational spacecraft, an example of NOAA collaboration in support of NASA's research program.

In addition to this collaboration between NOAA and NASA, international collaboration flourished, leading to a global network of geostationary satellites. France and the United Kingdom also contribute sensors flown routinely on the NOAA polar-orbiting satellites. Mutual backup internationally also is provided wherever possible. For example, during the Global Weather Experiment, NOAA moved a spare GOES satellite over the Indian Ocean and the European Space Agency operated it from a ground station they established in Spain. Today, NOAA is using a geostationary satellite borrowed from Europe for coverage of the Western Hemisphere until the new *GOES-8* can become operational.

Stagnation in the decade of 1980

What has happened in recent years and what is the state of affairs in the United States today, in the fourth decade since the launch of the first TIROS?

In 1982 NASA unilaterally ended its commitment to fund, develop, and test new generation spacecraft and sensors for NOAA's operational satellite system. *GOES-8* is the first new operational spacecraft to be developed since this decision. The development was funded by NOAA with apparently reluctant technical support provided by NASA. The new spacecraft is years late and the cost has more than doubled. Is this cause and effect?

In the 1980s there was a substantial decrease in NASA's research and development spacecraft compared to the decade before. Although planning for the Earth Observation Satellite program was initiated early in the decade, it is still having trouble getting off the drawing board. This is typical of the continuing stretch out in the decision-making and execution processes for a new satellite, now 8 to 10 years compared to 2 years for *TIROS-1*. This is not unique to space programs in the U.S. government. One cause of this certainly is the very high cost of these big

programs during a time of growing budget pressure. But it appears that there also has been a rapid growth in the whole federal decision-making and oversight processes. Is this stretch out resulting in bright young scientists and engineers seeking greener pastures in which they can see the significance of their contributions in less than half a working lifetime? If so, these programs and the nation will suffer from the loss of critical, unforeseen inputs that can and must be made by our best individuals.

Conclusions

In conclusion, reflecting on the history of the U.S. meteorological satellite program and the difficult situation both the research and operational activities appear to be in today, it may be time to reevaluate the following:

1) the federal decision-making and management process within which the program must operate,
2) how the contributions and ideas of bright individuals can effectively influence the satellite programs of the future, and
3) NASA's decision not to fund, develop, and demonstrate new prototype systems in support of the operational satellite program of the United States.[2]

Clearly the early years benefited from the national determination to become a leader in space following the launch of the first *Sputnik*. This led to the creation of NASA with a mandate to move ahead quickly, taking advantage of good ideas for both space research and applications, and attracted excellent talent to work on challenging problems. Do we need the equivalent of another *Sputnik-1* today before action can be taken to improve the current situation? Maybe so.

References

Greenfield, S. W., and W. W. Kellogg, 1951: Inquiry into the feasibility of weather reconnaissance from a satellite vehicle. USAF Project RAND Report R-218; unclassified ed. 1960, report N-365. 43 pp.

Kaplan, L.D., 1959: Inferences of atmospheric structures from satellite radiation measurement. *J. Opt. Soc. Amer.*, **49**, 1004.

[2] It remains to be seen how the 5 May 1994 Presidential Decision Directive NSTC-2 for "Convergence of U.S. Polar-Orbiting Operational Environmental Satellite Systems" will impact the current operational satellite program.

Verner Suomi

In the photograph above, Verner Suomi spoke with honor as he accepted the 38th IMO Prize at a ceremony held on 13 May 1994 at the University of Wisconsin—Madison. Suomi was honored for his participation in establishing the field of satellite meteorology and for the invention of the spin-scan weather camera.

The previous IMO winners have all been distiguished meteorologists who contributed significant theories and technological developments to the field of meteorology and related disciplines. The following lists the previous winners from the first to the last.

T. Hesselberg, C.-G. Rossby,* E. Gold,* J. Bjerknes,* J. Van Mieghem, K. R. Ramanathan, A. K. Angström, R. C. Sutcliffe,* F. W. Reichelderfer,* S. Peterson,* T. Bergeron,* K. Y. Kondratyev,* G. Sutton,* E. Palmén,* R. Scherhag, J. G. Charney,* V. A. Bugaev,* C. H. B. Priestly* and J. S. Sawyer* (both for the 18th prize), J. Smagorinsky,* W. L. Godson,* E. K. Federov, G. P. Cressman,* A. Nyberg,* H. E. Landsberg,* R. M. White,* B. Bolin,* W. J. Gibbs, J. J. Burgos and M. F. Taha (both for the 28th prize), T. Malone,* A. Davies,* H. Flohn,* M. I. Budyko,* F. K. Hare,* P. R. Pisharoty, R. E. Hallgren,* R. Fjortoft, J. A. Izrael, and V. E. Suomi.*

The 39th IMO Prize was not announced at the time of publication.

*AMS members

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TIROS Satellites and Satellite Meteorology

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