Chapter 32. Battlestar Galactica

Mission to Planet Earth seemed perfect for NASA. Measuring and deciphering natural and human-made global change is a complex task. A view from space is essential to monitor change on the 510,000,000 square kilometers of Earth's surface.

Global observations are only part of what is required. We also need measurements on the ground and in the ocean and atmosphere. Data interpretation depends on small-scale models of processes and global models to integrate all processes. Models and interpretations should be tested for the range of climates in Earth's rich paleoclimate history.

NASA managed a complex mission to Venus brilliantly, with an orbiting spacecraft, entry probes, theoretical studies and models. Scientists determined the nature and scale of the Pioneer Venus mission before it was even presented to engineers. Richard Goody and Don Hunten published the mission concept in *Science* magazine to be sure that NASA understood what was needed and to give the larger scientific community an opportunity to comment on the plan.[1]

In contrast, spacecraft plans for Mission to Planet Earth were hatched in the dark. Spacecraft plans were set before the scientific community had a chance to assess the science, required measurements, and the implications for instruments, satellite size and orbits.

Battlestar Galactica sprang from the minds of a handful of people within the walls of the NASA Headquarters building in Washington, DC. Battlestar Galactica is not the NASA name. It is a name we at the Goddard Institute and others used after we were stunned by the initial plans: about 20 instruments, some as large as automobiles on each of two giant platforms.

A lot happened between 1982 – when Richard Goody and Mike McElroy persuaded NASA Deputy Administrator Hans Mark of the need for a Mission to Planet Earth to carry out a broad-based scientific study of natural and human-made global change – and the 1989 emergence of the NASA Earth Observing System (EOS). EOS was the space observations component of Mission to Planet Earth. Hans Mark left NASA in 1984 to become Chancellor of the University of Texas system. Space Science influence on Mission to Planet Earth declined.

What followed was a tragedy, in my view. It was surely harmful to our institute and specific individuals, but it was also harmful to humanity. A mission strategy was set in motion that prevented the public from having timely quantitative knowledge of the full causes of climate change and the options to minimize adverse effects of climate change.

All the individuals in this story were well intentioned. My objective is not to cast blame, which I would deserve much of, but rather to expose the nature of how things work in our government, even in the more effective agencies. Perhaps it will point us toward needed changes.

The Earth Observing System became the focus at NASA Headquarters. Principal people defining the program were Burt Edelson, Shelby Tilford and Dixon Butler.

Edelson's background was in telecommunications satellite technology with Comsat Corporation. Edelson was college roommate of James Beggs – NASA Administrator from July 1981 through December 1985. Beggs hired Edelson to be NASA's Associate Administrator for Space Science and Applications when NASA was struggling to find a purpose for the expensive Space Shuttle.

Tilford and Butler had been involved in NASA ozone research. Their backgrounds were fitting preparation for programmatic leadership at NASA Headquarters. Work at Headquarters – facilitating acquisition of funding from Congress and dispersing funds to NASA Centers and universities – is not attractive to most scientists. Yet good management is crucial for mission success, and NASA historically has done well in finding people who excel in this service.

Successful program management demands extensive interaction with the scientific community, especially in early mission definition. That interaction was inadequate for the Earth Observing System. Mission definition may have been affected by directions from the highest levels at NASA, but nevertheless interviews of Tilford and Butler for the NASA Oral History Project[2] expose a shockingly constrained approach to mission definition in the years following the impressive Woods Hole workshop in 1982. Scientists were consulted about data needs, but the scientific community did not have a chance to assess and alter the basic spacecraft strategy.

Edelson and Tilford initially proposed huge polar-orbiting platforms to be carried to orbit by the Space Shuttle, likely requiring multiple launches with platform segments bolted together in space by astronauts. They did not understand that the energy needed for launch into polar orbit was too great for the Shuttle and a large platform. After realizing that the Shuttle had little role in the program, they continued to plan on large polar platforms with 12-24 instruments.

It is fine to examine such a concept for Earth observations, but it is crucial to seek scientific review and encourage alternative proposals. The scientific method requires skepticism of any first proposition. The truth is that we seldom get things right with our first concept. The absence of such scrutiny seems inconceivable for a program with a $50B price tag.[3] Failure to have an open early conceptual review dogged Mission to Planet Earth throughout its lifetime.

In stark contrast to their tight in-house definition of planned space hardware, Tilford and Butler did an exceptional job of encouraging input on the nature of Earth science research to be pursued by Mission to Planet Earth. They had strong motivation to court the scientific community. Congress would never pick up the tab, if the scientific community did not bless the project.

Tilford's choice of Francis P. Bretherton to chair the Earth Systems Science Committee, formed in 1983, was brilliant. Bretherton had been President of the University Corporation for Atmospheric Research and simultaneously Director of the National Center for Atmospheric Research in the 1970s. Bretherton gave up administration in 1980 and returned to research.

Bretherton is a genius. Look up Bretherton Equation in Wikipedia for an example of his ability in mathematics and physics. He used that nonlinear partial differential equation to study weakly-nonlinear wave dispersion. Don't worry about what that means.

Bretherton's parents gave him the middle name Patton. It fit. He had to marshal troops from disciplines that did not normally communicate with each other. Complexity of the Earth system was emerging. For example, a farmer fertilizing his field to improve crop yield, by affecting nitrogen fixation,[4] alters the amount of nitrous oxide (N_2O) emitted to the atmosphere. Nitrous oxide, popularly known as laughing gas, has a lifetime of about a century, more than enough time for much of it to waft into the stratosphere. There it causes chemical reactions that destroy ozone, which then allows more ultraviolet radiation to reach Earth's surface. Increased UV radiation affects plants as well as humans. See the complex feedback loops in the Earth system! Soil scientists must work with stratospheric chemists to understand the system.

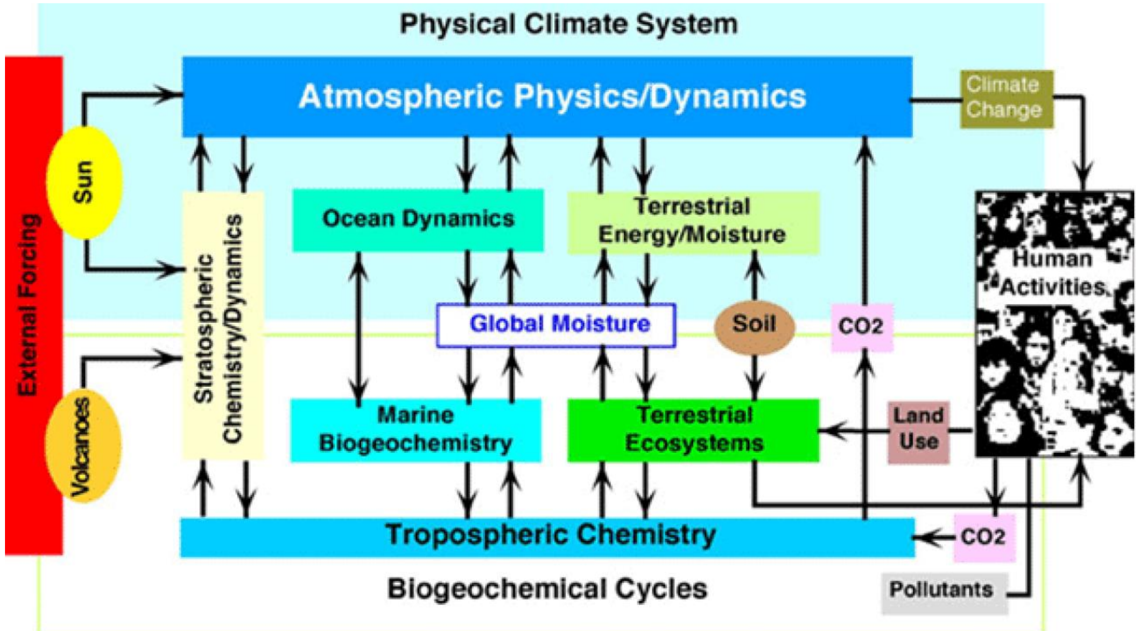

Fig. 32.1. Simplified "Bretherton Wiring Diagram."[5]

Bretherton spoke in a loud authoritative voice that avoided the need for electronic amplification. His normal volume was described as "one Bretherton." When he wanted to explain an important point or if he got excited his voice rose, and he was sometimes warned "Francis you are at two Brethertons!" Nobody minded that he dominated a meeting: he knew what he was talking about, tried to be in good humor, expressed emotion, and was often self-deprecating.

The main objective of the Earth System Science ("Bretherton") Committee was to produce a document describing the Earth system to help scientists and agencies understand how the many research areas fit into a global picture. It took years. A coherent summary of such a complex system requires the overall story to exist in one brain. That brain was Bretherton's. He often assigned himself the task of writing the summary of a section, which he sent to Committee members and other relevant people with some comments punctuated by "Whew!"

A preliminary document was produced in 1986 and the final version, *Earth System Science: A Closer View*, in 1988. The report of more than 200 pages includes a complex "wiring diagram" summarizing how Earth systems are interconnected and the simplified version in Fig. 32.1. The simplified Bretherton Wiring Diagram became an iconic summary of Earth's climate system, including natural and human-made forcings that drive climate change. The diagram was a useful tool that aided communication with students, policymakers and interested public.

It was a propitious moment, in 1988, for NASA to propose Mission to Planet Earth. How could Congress fail to provide funding, given ongoing dramatic climate events? Indeed, at the end of the year Time Magazine declared Earth to be "Person of the Year."

NASA issued an Announcement of Opportunity, anticipating new funds from Congress in 1989, soliciting proposals for satellite instruments and interdisciplinary science investigations of the principal global change issues. We prepared two proposals at the Goddard Institute.

One proposal, with Larry Travis as principal investigator, was a polarimeter to measure aerosol and cloud properties. A polarimeter is the only known remote sensing approach capable of defining the climate forcing by aerosols.

Our second proposal, for which I was the principal investigator, was an interdisciplinary study of the global carbon, energy, and water cycles. In other words, our topic was the entire Bretherton diagram. We asserted credibility based on composition of our team, which included Tony Del Genio, Inez Fung, Andy Lacis, Michael Prather, David Rind, Bill Rossow and Peter Stone.

However, we were distressed by the specific NASA plans for an Earth Observing System (EOS), which was dominated by huge satellite platforms in sun-synchronous polar orbits. A large platform is slow to construct and likely to experience delays and cost overruns that tend to squeeze out research and delay progress in the science.

We felt that priorities were backward. First there should be investment in brainpower – especially students and post-docs – as happened at the origin of NASA space science. Next are measurements that provide information soon. Some critical data can be obtained quicker with small satellites. Some measurements are best if made from a non-polar orbit.[6]

Bill Rossow, Inez Fung and I were probably the ones most responsible for questioning mission strategy. Our opinions became well known because Bill and Inez worked extensively with scientists at other organizations and I attended regular staff meetings at Goddard Greenbelt.

Our criticisms were not appreciated. Gerry Soffen, Project Scientist for the Mission to Planet Earth at Greenbelt, and my supervisor, Vince Salomonson, told me to hold any criticisms until Congress fully funded the program. That would be too late, I argued – we needed to question the program strategy before it was set in concrete.

Gerry Soffen called me a few days before the winning proposals for Mission to Planet Earth were to be announced. Our proposed science investigation of carbon, energy and water cycles was "just below the cutoff line and would not be funded." His explanation: Bob Dickinson's proposal, with objectives similar to ours, received a higher rating from a review panel. That did not surprise me. Soft-spoken Bob Dickinson, expert in everything from stratospheric dynamics to vegetation in climate models, was widely considered to be the smartest person in the field.

Gerry said that I must meet with Shelby Tilford. Tilford had absolute control on where the line was drawn; I could probably persuade him to move it down. That, too, was believable. Shelby operated like a tsar. A sign on his desk read: "The Golden Rule, he who has the gold rules."

The day before the NASA announcement Gerry called again. He was frantic. Why had I not contacted Tilford? This was our chance for funding; how could we survive without it? I said that perhaps we would seek funding from EPA or the Department of Energy. Gerry was perplexed and angry. From that point on our relationship was frigid.

Both of our proposals were selected: the polarimeter and the carbon, energy, and water cycles investigation. The title of the latter study was simplified to "The Theory of Everything" for our name tags when the 500 winning principal and co-investigators[7] got together for the first time at a week-long meeting at Goddard Space Flight Center in March 1989.

Principal investigators each had several minutes to describe their study. I knew that many scientists shared our concerns about EOS, so I used part of my time to raise two issues. First, investment in development of scientific brainpower and in research was underfunded relative to funding of hardware. Second, NASA made major decisions about observing systems before asking help of advisory committees, which could then only tinker around the edges.

Naively, I hoped to get open discussion of these issues. It did not happen. The organizers did not want such, and no other scientists joined the criticism. After I sat down, Gerry Soffen walked up from behind, put his hand on my shoulder and whispered: "You will never be allowed to speak at an EOS meeting again!"

What had gone wrong? Larry Travis described the problem as my "habit of blurting out the truth." The blurting part was right, for sure. That I lacked rhetorical skills was an understatement. I did not have the abilities to lead discussion of concerns that must have been felt by others. My lack of oral communication ability had not been a severe handicap in space science, because of authoritative leaders such as Don Hunten, Richard Goody and Tom Donahue, and NASA leaders such as Hans Mark and Tom Young, who listened to the science experts.

Perhaps such leaders could have made a difference for Earth science; perhaps they could have implemented a Mission to Planet Earth along the lines contemplated at the 1982 Woods Hole meeting chaired by Richard Goody (Chapter 23). Perhaps not.

A powerful, growing, force opposed any efforts to have science requirements drive resource allocation. I hope that exposure of this force may help taxpayers and political leaders contemplate and define a better approach.

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[1] Management of the Galileo mission to Jupiter was not quite as lustrous. The tortuous 20-year time-scale of the Galileo mission was in part a result of political decisions including use of the Space Shuttle to launch the spacecraft.

[2] Johnson Space Center, Earth System Science, oral histories.

[3] $50B was the cost estimate in 1989 for 30-year program in 1989 dollars, which exceeds $100B in 2020 dollars.

[4] Nitrogen fixation converts nitrogen in the air to ammonia (NH_3) or related nitrogenous compounds, especially by certain microorganisms, as part of the nitrogen cycle. Nitrogen is a critical element for plant growth. It is a major component of chlorophyll needed for photosynthesis and of amino acids, the key building blocks of proteins.

[5] National Research Council, *Earth System Science: A Closer View*. Washington, National Academies Press, 1988.

[6] The Earth Observing System had two platforms, both in sun-synchronous orbits with subsatellite track close to the poles with equator-crossing times at the same time of day every orbit, one of the platforms with equator-crossing time in mid-morning, the other in mid-afternoon.

[7] Almost 500 proposals were submitted in response to NASA's 1988 Announcement of Opportunity. NASA approved 30 instruments for development and 29 interdisciplinary science investigations.