Chapter 31. Battlestar Galactica

Mission to Planet Earth was perfect for NASA (Chapter 23). Measuring and deciphering natural and human-made global change is a complex task. View from space is needed to monitor change on the 510,000,000 square kilometers of Earth's surface, but that view must be only part of a comprehensive program of research and observations. NASA managed a complex mission to Venus superbly, with an orbiting spacecraft, entry probes, theoretical studies, and models. Scientists determined the nature of the Pioneer Venus mission before it was even presented to NASA engineers. The U.S. National Academy of Sciences had a study of the mission concept, led by Richard Goody and Don Hunten, who then wrote a paper[I] in *Science* magazine to give the larger scientific commumity an opportunity to comment on the plan.

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 prioritize the science, the required measurements, and the best options to achieve a sustainable observational program.

Battlestar Galactica sprang from the minds of a handful of people within the wall"s of NASA Headquarters in Washington, DC. Battlestar Galactica is not the NASA name. It is a name that we at the Goddard Institute used for the Earth Observing System (EOS), the space observations component of Mission to Planet Earth. We were stunned by the plan for EOS, which had about 20 instruments, some as large as automobiles, on each of two giant platforms. Such mammoth EOS space hardware would inherently be slow to construct and expensive, overwhelming the Mission to Planet Earth program. Such an approach would not be nimble, capable of rapid adjustment in response to developing scientific understanding; thus, it was far from optimum for the purpose of understanding the causes of climate change and the policy implications.

All people in this story were well intentioned. My objective is not to cast blame, which I must share, but rather to expose the nature of how things work in our government, even in the more effective agencies. Although at first glance the EOS debacle appears to have been self-inflicted by NASA, we will find, eventually, it to be an example of the role of money and special interests in the way government operates. That is a problem that can and must be fixed.

Principal people who defined the EOS program were Burt Edelson, Shelby Tilford and Dixon Butler. Edelson's background was in telecommunications satellites with Comsat Corporation. Edelson was the college roommate of James Beggs, the NASA Administrator from July 1981 to 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 backgrounds in NASA ozone research, fitting preparation for program management at NASA Headquarters. The task of NASA Headquarters is to facilitate acquisition of funding from Congress and manage dispersal of funds to NASA Centers and universities. Such work is not attractive to most scientists, but good management is crucial for mission success and NASA has historically done well in finding people who excel in this service.

[I] The Goody and Hunten paper was based on a National Academy of Sciences study *Venus: Strategy for Exploration*, chaired by Goody and Hunten and including about 20 of the most relevant researchers in the world.

Perhaps Administrator Beggs placed constraints on the nature of the Earth Observing System, yet lower management levels can question the wisdom of instructions from above. Indeed, NASA employees have a duty to draw attention to dangerous instructions – whether the issue concerns launch of a spacecraft carrying humans or launch of an observing program that will affect the readiness of the world to deal with a climate crisis that was certain to emerge in coming decades. Given that situation, interviews of Tilford and Butler for the NASA Oral History Project[1] expose a shockingly constrained approach to EOS mission definition. Edelson and Tilford initially proposed huge polar-orbiting platforms carried to orbit by the Space Shuttle in multiple launches, with platform segments bolted together by astronauts. They did not understand that the launch energy needed for polar orbit was too great for the Shuttle. Even after realizing that the Shuttle had little role to play, 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 examine alternatives. The scientific method requires skepticism of any proposition; it is unusual to get things right in a first concept. The absence of such scrutiny is puzzling given the $50B price tag estimated for the program[II] and the availability of probably the best scientist in the world to lead such a review: Francis Bretherton.

Francis P. Bretherton was a genius. Look up Bretherton Equation in Wikipedia for a flavor of his ability in mathematics and physics.[2] Bretherton could comprehend the array of scientific disciplines that compose Earth sciences and communicate understanding of this Earth science panorama. Bretherton was Director of the National Center for Atmospheric Research in the 1970s, but he gave up administration in 1980 to return to research. Thus, when NASA conceived plans for an Earth System Sciences Committee in 1983, Bretherton was the ideal candidate to lead the committee. The objective was to involve the Earth sciences community in the definition and justification for the proposed Mission to Planet Earth. NASA had strong motivation to court the scientific community. Congress would not pick up the huge tab for Mission to Planet Earth, if the scientific community did not bless the project. However, Bretherton was committed to his research and teaching responsibilities at the University of Wisconsin, and he thus rejected Shelby Tilford's invitation to chair the NASA Earth System Sciences Committee as it was being formed.

Ruth Levenson (Angel #1, Chapter 24) drew Francis Bretherton into NASA's Mission to Planet Earth program. Ruth was persistent and assiduous in organizing monthly Global Habitability seminars. Bretherton was one of the first scientists that we identified as a preferred lead speaker for one of the seminars. In our pre-seminar discussion with Bretherton, we emphasized that the hallmark of the global habitability program proposed at Woods Hole was that it must be science-driven, and that the highest levels at NASA supported the concept of such a major U.S. initiative. Bretherton credited me with persuading him to reconsider and accept chairmanship of the Earth System Sciences Committee,[III] but Ruth Levenson deserved the credit.

Bretherton's leadership of the Earth System Sciences Committee was inimitable. 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, in fertilizing his field to improve crop yield, alters the amount of nitrous

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[II] $50B was the cost estimate in 1989 for 30-year program in 1989 dollars (exceeds $100B in 2020 dollars).
[III] See "Bretherton" in *Documents*.

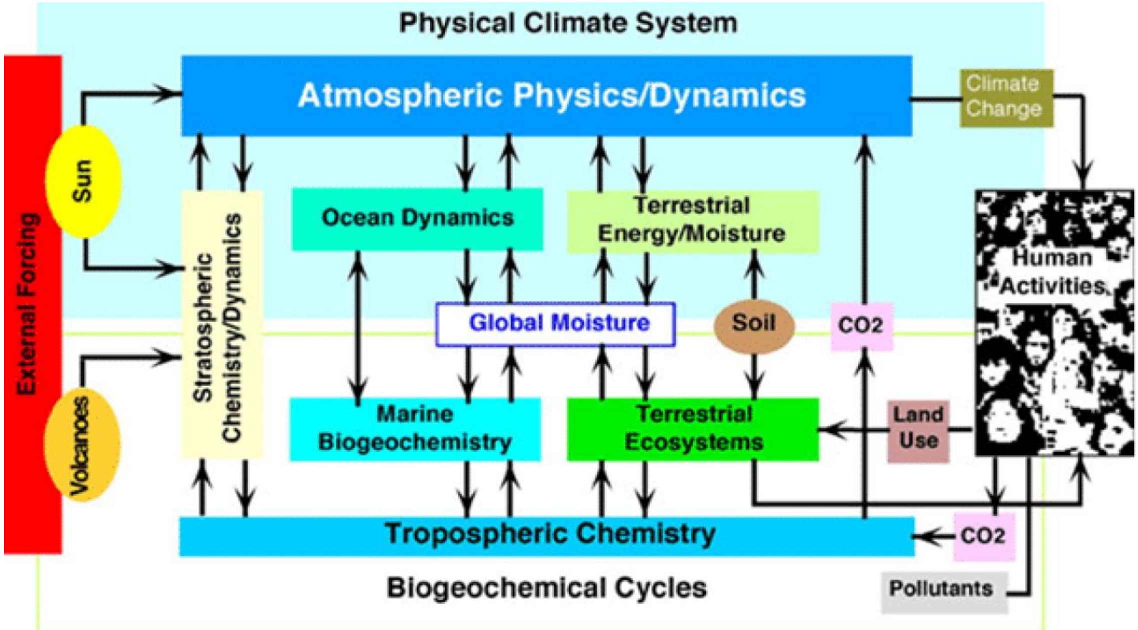

Fig. 31.1. Simplified "Bretherton Wiring Diagram."

oxide (N_2O) emitted to the atmosphere by affecting nitrogen fixation.[3] 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. Thus, we see the complex feedback loops in the Earth system! Soil scientists must work with stratospheric chemists to understand the system.

Bretherton spoke in a loud authoritative voice that avoided the need for electronic amplification. His normal volume was described as "one deci-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 deci-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 task of the Earth System Sciences ("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*,[4] in 1988. The report of more than 200 pages includes a complex "wiring diagram" summarizing how Earth systems are interconnected and a simplified version (Fig. 31.1). This simplified Bretherton Wiring Diagram became an iconic summary of Earth's climate system, including the natural and human-made forcings that drive climate change. The diagram was a useful tool that aided communication with students, policymakers and interested public.

The year 1988 was a propitious moment 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 1988, Time Magazine declared Earth to be "Person of the Year."

Thus, NASA issued an Announcement of Opportunity, anticipating new funds from Congress in 1989. The Announcement sought proposals of both satellite instruments and interdisciplinary science investigations of global change. 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 to investigate the entire Bretherton diagram! We asserted credibility in such a broad study based on the composition of our team, which included Tony Del Genio, Inez Fung, Andy Lacis, Michael Prather, David Rind, Bill Rossow and Peter Stone.

We became increasingly concerned, during the year leading up to these proposals, about lack of connection between NASA plans of observations and the Earth science that Bretherton brilliantly described. Scientists were consulted about data needs, but the scientific community did not have a chance to assess and alter the basic spacecraft strategy. We were distressed that NASA seemed to still prefer giant platforms for an Earth Observing System (EOS) with many instruments. 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 priority 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.

Bill Rossow, Inez Fung and I were 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. Vince Salomonson, who was Director of Earth Sciences at Goddard and my supervisor,[5] told me to hold criticisms until Congress more fully funded the program. That would be too late, I argued – we needed to question the program strategy before it was set in concrete. A few days before the winning proposals for Mission to Planet Earth were to be announced, Gerry Soffen, Project Scientist for Mission to Planet Earth, called to tell me that our proposed science investigation of carbon, energy and water cycles was "below the cutoff line and would not be funded." He said that I should contact Shelby Tilford, who had absolute control on where the cutoff line was drawn; I could persuade him to move the line down.

Tilford operated like a dictator and wanted people to know it. A sign on his desk read: "The Golden Rule, he who has the gold rules." I was certain that Soffen was Tilford's emissary, and that Tilford wanted a pledge of loyalty, termination of any criticism, in return for funding our proposal. There was no chance that I would call Tilford. I doubted that the review committee rated us so low and that Tilford could leave GISS scientists out in the cold when a huge new NASA program was announced. The day before the NASA announcement Soffen called again. He was frantic. Why had I not contacted Tilford? It was our last 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 day on, our relationship was frigid.

When winning proposals were announced, our polarimeter and our carbon, energy, and water cycles investigation were both included. When the principal and co-investigators of the winning teams got together for a week-long meeting at Goddard Space Flight Center in March 1989, the meeting organizers provided name tags for the approximately 500 participants. To fit the title of our investigation on the name tag, they simplified it to "The Theory of Everything." Principal investigators each had several minutes to describe their study. I knew that many scientists shared our concerns, so I used part of my time to raise two issues. First, investment in young scientists and in global change research was underfunded relative to funding of hardware. Second, NASA made the major decisions about observing systems before asking help of an advisory committee, which could then only tinker at the edges. I hoped to get open discussion of these issues, but it did not happen. The organizers did not want that, and other scientists did not join 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 said the problem was my "habit of blurting out the truth." The blurting part was right, for sure. That I lacked rhetorical skills was an understatement. On the other hand, I could write reasonably well. As we listened to the other principal investigators describe their proposed investigations without questioning the EOS strategy, it was clear that we needed another approach to explain our criticisms of EOS.

Dixon Butler, with a low-key, thoughtful, personality, provided the best chance for a favorable reception, so I began writing a **letter**[6] to him on the "brainpower" issue during the EOS meeting and sent it a few days later. Butler's response, reported in an article[7] in *Science*, was supportive; he said that he would tax the EOS hardware budget 0.25% to generate funding for students and postdocs. Our thought was for a program analogous to that of the space sciences in the 1960s, casting a wide net for the best students, even those unaffiliated with an EOS team. The program could be administered by the National Research Council, with winning students allowed to choose the government laboratory or university best suited to their post-doctoral research topic, including an option to move from one place to another during the post-doc tenure (as Inez Fung had moved from Greenbelt to New York during her post-doc). Such a program would provide equal opportunity to all young people.

Although I continued to advocate for such a program with Senators Gore and John Glenn,[8] we were soon overwhelmed by the more difficult task of explaining why observations additional to those planned for the EOS platforms were essential, if future generations were to understand the causes of climate change and the action required to stabilize climate. This objective gave rise to the concept of Climsat, a small satellite mission.

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

[2] The Bretherton Equation is the nonlinear partial differential equation that he used to study weakly-nonlinear wave dispersion. Don't worry about what that means.

[3] 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.

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

[5] Goddard had been reorganized again, with GISS pushed down to layer four in the hierarchy. The layers were: Goddard Director, Director of Space and Earth Sciences, Director of Earth Sciences, Chief of the Goddard Institute, although I continued to use the informal title of director (small d) of GISS.

[6] Letter to Dixon Butler, EOS Program Scientist, NASA, Washington, DC 20546, 27 March 1989.

[7] Marshall, E., Bringing NASA Down to Earth, *Science* **244**, 1248-51, 1989
[8] I sent a letter to Senator Gore and gave a copy of it to Senator Tim Wirth. When a staffer for Senator Glenn asked me to stop by Senator Glenn's office to discuss "NASA priorities," I sought advice of Prof. Van Allen, and focused my priority suggestion on such educational opportunity for young people.