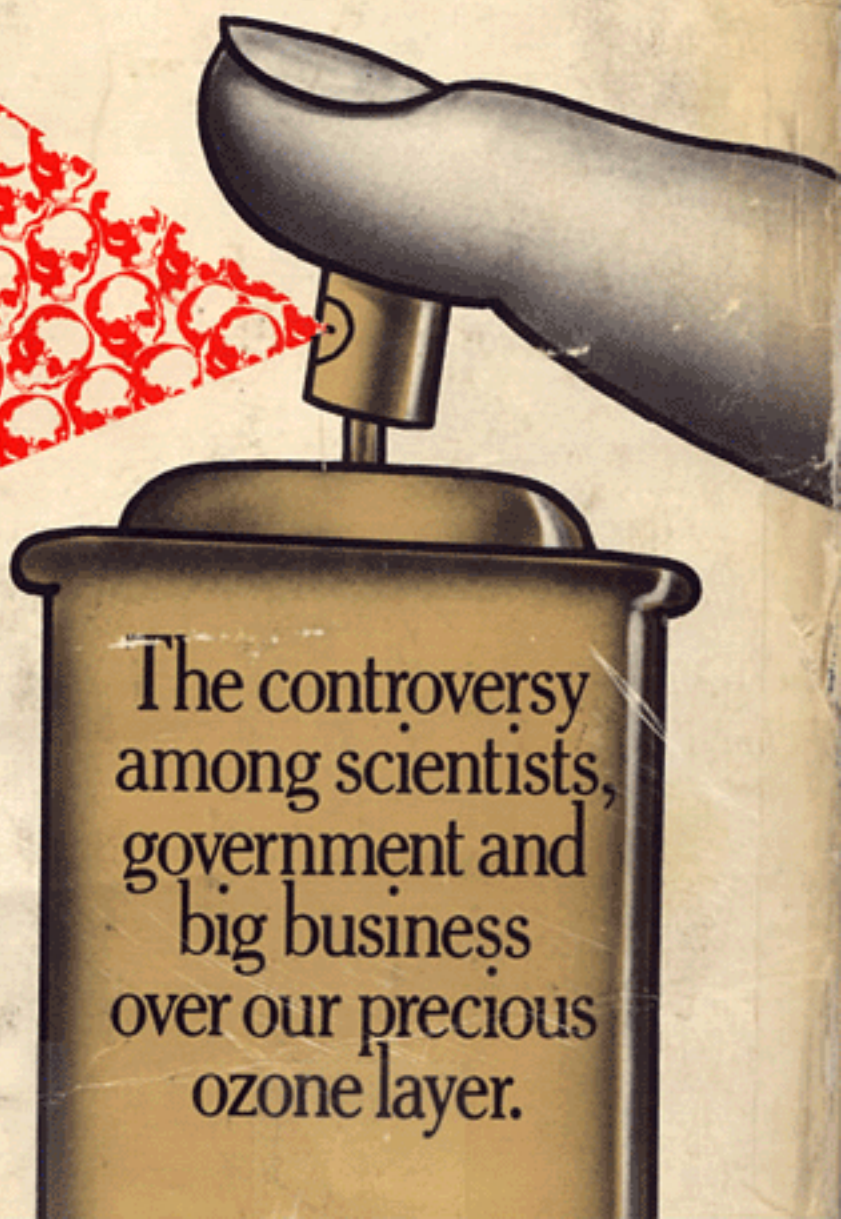


# THE OZONE WAR

LYDIA DOTTO and  
HAROLD SCHIFF



The controversy  
among scientists,  
government and  
big business  
over our precious  
ozone layer.

## CHAPTER SIX

### *Shuttle Diplomacy*

Once upon a time there lived in the land of *IAGA*, in the kingdom of *Aeronomy*, strange creatures called *aeronomers*. Little was known about these creatures because they lived most of their lives in the remote areas of the kingdom, more than 60 kiloleagues from Earth.

Not so long ago a part of their kingdom, known as *Stratos*, was threatened by the invasion of a flock of big birds who make noises, that sound something like—sst. Some of the creatures of *Aeronomy* rushed to *Stratos* to try to discover what these birds might be doing to their kingdom. Some came because they heard these birds could also lay golden eggs.

We soon learned that there are three kinds of *aeronomers*. There is a group of high priests called *modelers*. They never go outside their temples where they try to prophesy what the big birds will do by examining the entrails of large animals called *computers*. Another group, who appear to be the worker drones called *experimenters*, spend most of their time in noisy, smelly rooms called *laboratories* playing with little boxes whose purpose seems to be the generation of random numbers called *data*. A strange relationship exists between the *modeler* priests and the *experimenters*. The priests feed the *data* to the *computer* animals and then study their entrails. They then tell the *experimenters* what kind of new *data* the animals need and the *experimenters* rush back to their *laboratories* and make more black boxes.

The third group is called *observers*. They also make black boxes but they throw their boxes into the sky. Most of the time the black boxes break. Sometimes they too give *data* which the high priests also give to their animals. However, the animals sometimes get sick if they eat this *data* and may even die if too many different kinds of *data* are fed to them at the same time. However, the high priests

have become very clever at getting their animals to accept almost anything.

The diet of these animals seem to lack one essential nutrient called *transport data*. Unfortunately, these *data* are grown mostly by *dynamicists* who live in the land of *Tropos*. Only recently have the borders between *Tropos* and *Stratos* been opened to allow *dynamicists* and *aeronomers* to talk to each other.

—HAROLD SCHIFF, opening remarks,  
IAGA meeting, Kyoto, Japan,  
September 1973.

The problem of chlorine in the earth's atmosphere was first seriously discussed by experts in the fields of stratospheric chemistry and physics in September 1973. The scene was an international scientific meeting in Kyoto, Japan—a meeting that very nearly didn't happen, for reasons referred to only obliquely in the last sentence of Schiff's opening remarks.<sup>1</sup>

The Kyoto meeting had, in fact, precipitated an outbreak of hostilities within the international scientific associations. It was the latest round in the continuing jurisdictional dispute over the regions of the earth's atmosphere. Blockades were figuratively thrown up around the stratosphere. There was talk of invasion. There was talk of collision. There were summit meetings to resolve the issue.

It all started when Marcel Nicolet suggested that the meeting in Kyoto include a symposium on the aeronomy of the stratosphere and the mesosphere (the region above the stratosphere). Nicolet, a Belgian, was one of the founders of aeronomy (the science of the atmosphere) and a power in international scientific affairs. He made his recommendation to the sponsors of the Kyoto meeting, the In-

<sup>1</sup> Schiff was editor of a special volume of the *Canadian Journal of Chemistry* in which the proceedings of the Kyoto meeting were to be published. He was urged by several people who heard his remarks to include them in the proceedings, but this did not meet with the approval of the editors of the Canadian journal, who thought the remarks too frivolous for a serious scientific document. In consequence, they were removed from the regular editions of the Canadian journal, but Schiff insisted on their inclusion in the copies that *CJC* was publishing under contract to the CIAP program.

ternational Association of Geomagnetism and Aeronomy, known as IAGA. IAGA is one of the associations of the International Union of Geodesy and Geophysics, known as IUGG. The executives of both groups agreed to the symposium, and Nicolet proceeded to organize it.

His activities immediately provoked the wrath of another group, the International Association of Meteorology and Atmospheric Physics, known as IAMAP. This association, composed primarily of meteorologists, was already planning to hold a meeting on the stratosphere in Melbourne, Australia, in January 1974. IAMAP officials were incensed that IAGA was contemplating an earlier meeting on the same subject; they considered this to be in the nature of a preemptive strike. IAMAP had staked out the troposphere and the stratosphere, relegating IAGA to the mesosphere. They insisted that IAGA not cross the territorial borders. The fences were up. Passports were required.

A series of angry letters began flashing back and forth. One IAMAP official protested IAGA's activities. IAGA was proposing to "invade those portions of the atmosphere in which IAMAP has long been recognized as the competent body." He warned that a serious situation threatened to erupt.

A suggestion by Nicolet that IAMAP cosponsor the Kyoto meeting was rejected by IAMAP officials. Affronted, Nicolet pre-emptorily quit the Kyoto meeting. The excitable Belgian had been so incensed by a letter he had received from another IAMAP official, Will Kellogg of the National Center for Atmospheric Research in Boulder, Colorado, that he also announced that he was withdrawing from a commitment to give the first Sidney Chapman lecture at the University of Colorado in Boulder. Sidney Chapman, as we have seen in Chapter Two, was the father of aeronomy, and being offered the Chapman lectureship was a significant honor; it proclaimed Nicolet the inheritor of Chapman's mantle. But Nicolet would not set foot in Boulder as long as Kellogg was there.

At this point, Schiff reluctantly inherited the chairmanship of the symposium and the political mess it had wrought. Another Belgian scientist, Marcel Ackerman, was deputized by a group of Nicolet's friends and colleagues to visit Schiff in Toronto to urge him to accept the chairmanship and, in particular, to find a way of inveigling

Nicolet back into the fold. This was accomplished by inviting Nicolet to give the keynote paper at Kyoto.

Schiff had put a condition on his acceptance of the chairmanship of the symposium: A way had to be found to defray the large travel costs the invited speakers would incur in getting to Japan. It was the only way to ensure that the best scientific talent could attend. Schiff spoke to Alan Grobecker to see if CIAP funds might be made available for this purpose.

Grobecker was enthusiastic. He thought the timing was right. The CIAP program had reached the halfway mark, a lot of data had been collected, and a major meeting on the stratospheric work seemed appropriate. Grobecker was equally enthusiastic about the IAMAP meeting scheduled for Australia in January, and he saw no conflict between the two. IAGA could concentrate on the chemistry of the stratosphere and the refinement of the computer models used to predict stratospheric effects; IAMAP could concentrate on transport—air motions—and on the meteorological aspects of the problem. To keep peace, he gave the squabbling children \$50,000 to help with travel. And so, on September 10, the scientists gathered in Kyoto.

The issue of chlorine chemistry in the earth's stratosphere was introduced at the Kyoto meeting by Richard Stolarski of the University of Michigan. Although he did not talk about the shuttle (for reasons we'll discuss later), this work had been done by a team of researchers at Michigan under contract to the National Aeronautics and Space Administration (NASA), which had become concerned about the possible stratospheric impact of the shuttle.

The story of the space shuttle really started back in early 1972, when NASA announced that solid-propellant rocket motors had been chosen to boost the shuttle into orbit. At that time, no one worried too much that the propellants would produce hydrogen chloride (HCl), which could be broken down in the stratosphere to produce chlorine atoms.

In July 1972, NASA's final environmental-impact statement on the shuttle revealed that HCl would spread along the shuttle's trajectory from ground level to the upper atmosphere, with the largest amount being deposited directly into the stratosphere. The pro-

jected fifty flights a year would dump some fifty-five hundred tons of HCl into the stratosphere annually.

The environmental-impact statement devoted considerable attention to the effects of HCl in the regions of the atmosphere below and above the stratosphere, but not in the stratosphere itself; there was no indication that the stratospheric effects of HCl were even considered and rejected as unimportant. Interestingly enough, two other shuttle effluents, carbon dioxide and water vapor, *were* considered. The impact statement concluded that neither would have unacceptable stratospheric effects and that "no negative environmental effects in the stratosphere are expected as a result of shuttle operations." It ended, on a grand note, claiming that shuttle-launched satellites will help to improve the management of the environment and the earth's natural resources. "This nation's short-term investment in the space shuttle program will result in a long-term improvement of the global environment for future generations."

The environmental-impact statement's omission of stratospheric HCl effects was seemingly so blatant that one is tempted to conclude that it had to be deliberate. But a more likely explanation is that NASA simply did not have much expertise on the subject of stratospheric chemistry at the time. Ron Greenwood, later head of NASA's stratospheric research program, adds that the HCl problem was ignored because "it was unheard of. In hindsight, it was obvious that it should have been picked up, but the impact statement was prepared a year before anybody was seriously thinking about the possible effects of chlorine."

In fact, the first draft of the impact statement was released before even the SST threat to the ozone layer had been widely recognized. When the final statement came out in early 1972, stratospheric chemistry was still not well understood, and certainly the problem of chlorine in the stratosphere had not become an issue in scientific circles. Though many scientists outside NASA knew that chlorine atoms were ozone eaters, few if any knew that the shuttle would be a source of stratospheric chlorine.

However, the impact statement left many questions unanswered, and a number of NASA scientists were dissatisfied with it. Even before it was officially released, a reinvestigation of the shuttle's envi-

ronmental effects was under way. NASA's Marshall Space Flight Center awarded a contract to a team of researchers at the University of Michigan to consider environmental effects that may have been missed. At about the same time, a Shuttle Exhaust Effects Panel was set up within NASA with Ron Greenwood as chairman.

Near the end of 1972, Rich Stolarski, who is now with NASA but was then a member of the University of Michigan team, went to spend a year's sabbatical with Bob Hudson, a NASA scientist at the Johnson Space Center in Houston. Hudson, Stolarski, and Ralph Cicerone, another member of the team back in Michigan, discussed the shuttle/chlorine work on the phone about once a week.

Cicerone and Stolarski were yet another team of "outsiders" when it came to problems of the ozone layer. Like Rowland and Molina, they were not stratospheric chemists. Unlike Rowland and Molina, they were not even chemists. Cicerone had received his degree in electrical engineering and both he and Stolarski, whose training was in physics, had been doing work on the ionosphere, a region of the atmosphere above the stratosphere.

Stolarski remembers that they were looking around for something new to do and were attracted by all the activity in the stratosphere. But it was not easy to break into that game. They were not in the CIAP program and "you couldn't just hop into the SST thing. It had been going for too long and we didn't have the credentials." So they decided to take "something that nobody cared about, which was chlorine. It looked like a nice, *quiet* piece of the stratosphere to cut off and maybe get a paper or two while we were learning and nobody would bother us." In fact, they saw the shuttle contract as little more than a means of obtaining the money to begin this research.

It was through conversations with Don Stedman at Michigan that Cicerone and Stolarski first got the idea that ozone might be affected by chemical reactions involving HCl and its decomposition products. Stedman, a British chemist, advised Cicerone to write to Stedman's former research director, Michael Clyne, for information about stratospheric chlorine chemistry. Clyne wrote back with the rate constant (speed) of the reaction between atomic chlorine and ozone. This was the first half of the chlorine chain, but the Michigan group did not immediately realize that in fact they were

dealing with a chain. It was near the end of 1972, during one of the three-way conversations among Cicerone in Michigan and Stolarski and Hudson in Houston, that they caught onto this fact. Initially, however, they got the wrong chain. The first part—the reaction between chlorine atoms and ozone—was right, but they closed the chain with another reaction that turned out not to be important.

Unknown to the Michigan group, the shuttle/chlorine problem had already been worked out by a team of researchers at the Lockheed Palo Alto Research Laboratory. The team, headed by Hiro Hoshizaki, had done this work on a contract from the CIAP program. They had been asked to study engine exhausts, and CIAP manager Alan Grobecker told them to include in their study the exhausts from rocket engines, including the shuttle. They got onto the chlorine question because Hal Johnston had alerted them to the potential of the chlorine chain for ozone destruction.

According to one member of the Lockheed research team, they tried to interest NASA in their work in September 1973; they were in Washington talking to the CIAP people and took the opportunity to try to set up a meeting with NASA. The attempt failed; their top management reportedly phoned them in Washington and told them to back off. It was an awkward situation; the Lockheed Propulsion Company was, at that time, competing for the contract to build the shuttle booster engine. In November 1973, the contract went to Thiokol Chemical Corporation of Utah (the home state of both James Fletcher and Frank Moss, at that time NASA administrator and chairman of the Senate Space Committee, respectively). In January 1974, Lockheed challenged the award of the \$106 million contract to Thiokol on economic grounds. The challenge was not successful and it was only after the dust settled were the Lockheed scientists permitted to discuss their results formally with NASA. By March 1974, their funding from CIAP had run out, and they tried to get NASA support to continue their research. NASA was not interested; Hoshizaki got the impression that the space agency preferred to have the work done by university researchers on the grounds that research by aerospace industry scientists might be considered somewhat suspect in congressional hearings. So the team, which did not really have a good computer modeling capability



anyway, published their results in their CIAP report and dropped the whole matter.

By that time, the chlorine issue was already being discussed within NASA by three space agency scientists: Bob Hudson at the Johnson Space Center, Jim King at NASA's Jet Propulsion Laboratory, and I. G. Poppoff of NASA's Ames Research Center. And in the spring of 1973, the Michigan group made its first formal presentation to NASA's Shuttle Exhaust Effects Panel and later submitted a written report (still containing the incorrect chlorine chain) that concluded that, on a global scale, chlorine compounds "may be significant destroyers of ozone. . . ."

Through the spring and summer of 1973, NASA started putting together a program to study the shuttle's atmospheric effects, and senior officials in the office of manned spaceflight and at NASA headquarters were informed of the problem. By mid-1973, according to Cicerone, NASA began leaning on the Michigan scientists to keep quiet about the shuttle chlorine problem. Cicerone, who was project leader, said he began receiving calls perhaps three or four times a week, telling them "to keep quiet about this until a lot more work had been done or to try to downplay it whenever we had to talk about chlorine cycles."

As far as Cicerone was concerned, the most blatant attempts at suppression involved two scientific papers prepared by the Michigan researchers, one for the Kyoto meeting and another submitted to *Science* magazine.

Cicerone and Stolarski found out about the Kyoto meeting from Bob Hudson, who had been invited to give a paper there. During the summer of 1973, he encouraged the Michigan scientists to submit an abstract on their chlorine work. They did so, listing Hudson as a coauthor and omitting any mention of the shuttle. According to Hudson, he was the one who suggested the omission. He was not certain whether the shuttle really was a problem and felt it was sufficient to get the chlorine chemistry out in the open to see if the Michigan team had it right. Consequently, the paper dealt only with natural sources of HCl, primarily volcanos.

Hudson did not realize, until he saw the preliminary program of

the Kyoto meeting, that his name had been put on the abstract. This was awkward for him because such things are supposed to be cleared by NASA first. Cicerone felt strongly that Hudson's name should be on the paper. In fact, Cicerone felt more strongly about it than Hudson himself did. Cicerone believes that NASA was pressuring Hudson in its continuing attempt to keep the shuttle problem quiet, but it seems more likely that Hudson was simply disinclined to push the issue of having his name on the paper, perhaps in anticipation of the hassles that might ensue.

It was in part to protect Hudson that Stolarski did not discuss the shuttle at Kyoto. Instead, he gave a brief summary of the work done by the Michigan team, focusing on volcanic eruptions as a source of stratospheric chlorine.

The paper came under strong attack from Mike McElroy of Harvard University. McElroy thought there were serious errors and omissions in the chemistry, and he particularly challenged Stolarski's assertions regarding volcanic sources of chlorine. The Harvard group, he said, had also looked at the effects of volcanos and did not believe they were a major contributor to stratospheric chlorine.

Others in the audience thought the chlorine problem was a complete red herring. They knew that atomic chlorine would destroy ozone, but there didn't seem to be any really significant source of chlorine in the stratosphere. They were unimpressed with the case Stolarski was making for volcanos and wondered why Stolarski and McElroy were wasting everyone's time. Of course, what they did not know was that the two were actually talking about the shuttle. We have seen that Stolarski chose not to enlighten them. Nor did McElroy.

Mike McElroy is one of the most flamboyant personalities associated with the ozone controversy. He is known for the quickness of his mind and his facile ability to assimilate and understand new ideas and information rapidly; it is a talent that disconcerts colleagues and competitors alike. McElroy is extremely competitive and favors a strongly confrontational *modus operandi* in scientific exchanges. In consequence, a series of marked personality clashes has characterized his involvement in the ozone controversy.

McElroy, an Irishman with a shock of red hair and a pale complexion, can be a walking advertisement for the effects of ultraviolet radiation. He once made a memorable impression on Thomas Jukes, a microbiologist who writes a regular column for *Nature* magazine. Jukes wrote of Mike:

. . . on the beach at Cape Canaveral in Florida, I saw a red-headed man, sunburned to look like a boiled lobster, applying Novocain cream to his glowing back. The only unusual circumstance was that the man was Mike McElroy, whose field is the physics and chemistry of planetary atmospheres and who has loudly warned us against the ultraviolet perils of destroying the ozone layer. . . . Surely he, of all people, should have kept his shirt on.

Unlike Stolarski and Cicerone, McElroy was already directly involved in studying the ozone problem; he was one of those engaged in the CIAP study. Ironically enough, however, it was not his CIAP work that brought McElroy to the shuttle problem; he came to the question of chlorine chemistry by way of Venus. As an expert on planetary atmospheres, he had for many years been involved in NASA's program of exploring other planets with unmanned spacecraft. In 1970, he and his colleagues were studying the chlorine chemistry of the atmosphere on Venus, and their papers on Venus contained the correct chain reaction that was relevant to the ozone problem on earth.

A graduate student had broached the idea of studying chlorine in the earth's lower atmosphere, but McElroy did not think the question was very promising as a research topic, and the matter was not pursued at the time.

According to McElroy, he first began to think seriously about chlorine in the earth's atmosphere in mid-1972, after he saw NASA's environmental-impact statement on the shuttle and recognized it as a potential source of stratospheric chlorine. He and his associate, Steve Wofsy, started working on the chlorine problem, but they did not immediately focus on the shuttle per se. Instead, McElroy said, they concentrated on identifying and studying natural sources of chlorine, including volcanos.

They also calculated how much ozone would be destroyed for a given input of chlorine, without specifying where the input was coming from. This work took them the better part of a year, and it was completed only a few days before McElroy left for the Kyoto meeting.

McElroy was an invited speaker at Kyoto. In his hour-long review of atmospheric photochemistry, he dealt primarily with the role of  $\text{NO}_x$ . He mentioned chlorine chemistry only passingly, if at all.

Stolarski spoke after McElroy, and it was during the question period following that he and McElroy got into their wrangle over chlorine from volcanic sources. Neither said anything about the shuttle, though they both knew it to be a chlorine source.

Stolarski said that the main reason he kept quiet was because he did not believe that the shuttle's impact on the ozone layer would be large, and he was more concerned about the chlorine chemistry itself. "I didn't think I was talking about the shuttle. I was putting what I considered the scientific end of the paper out front at a scientific meeting."

The Michigan team did not know that McElroy also knew about the shuttle, although Stolarski said he knew from rumor that Mike was working on chlorine in the lower atmosphere.

McElroy, on the other hand, said he did know at the time of the Kyoto meeting that the Michigan researchers were working on the shuttle. He denies that NASA pressured him to keep quiet about the shuttle; he did not mention it in Kyoto, he said, because there was still considerable uncertainty about how serious the effect would be. It was all "entirely speculative."

The result was that the Kyoto meeting drew to a close with most of the world's top experts in stratospheric chemistry none the wiser about the shuttle's potential impact on the ozone layer.

Stolarski's attempt to spare Bob Hudson embarrassment by not mentioning the shuttle proved to be fruitless. A trip report prepared by another NASA scientist erroneously stated that Hudson had given the chlorine paper and that it had been obvious he was referring to the shuttle. A minor flap ensued, but, fortunately for Hudson, the report temporarily got lost in the maze of the NASA bu-

reaucracy, and by the time it surfaced, he had been able to quieten people down.

After the Kyoto meeting, Schiff began assembling the material for the special volume of the *Canadian Journal of Chemistry*. He spent the better part of the last three months of 1973 chasing after the invited speakers for the final versions of their papers.

When the Wofsy and McElroy paper arrived in late November, Schiff was a little taken aback to discover that it was dominated by a discussion of chlorine chemistry, rather than the nitrogen chemistry that had made up the bulk of McElroy's presentation in Kyoto. It is perfectly acceptable for scientists to update such papers, but the changes are normally of a rather minor nature. McElroy explained that he and Wofsy were about to publish the chlorine work anyway and they had simply decided to put it into the paper they had to do for the *Canadian Journal of Chemistry* rather than write a second paper. This revised paper explicitly stated that the impetus for their chlorine work was the shuttle, but they did not calculate the shuttle's impact, which they said could not be reliably assessed until the natural chlorine cycle was better established.

At the end of January, long after the deadline had passed, Schiff got a rather frantic call from Stolarski asking whether the Michigan paper could still be included in the published proceedings. This call had an interesting history. After the Kyoto meeting, Cicerone and Stolarski had prepared a paper that they submitted to *Science* magazine. This paper, which did not have Hudson's name on it as a co-author, did mention the shuttle, and Cicerone soon felt himself to be under considerable pressure from NASA not to publish it. He said he began to get phone calls from NASA headquarters, some of which "I construed as threats that our support would be cut off if we didn't hold off publishing this."

He also remembers a December 1973 meeting at the NASA Ames Research Center where he and Stolarski were pulled aside by a group of NASA scientists and "warned that we shouldn't persist in having our *Science* paper published. They encouraged us to withdraw mention of the shuttle if it should be published. They let us

know they weren't speaking personally, because they were our friends, but they were representing higher interests in NASA."<sup>2</sup>

Stolarski's interpretation of what happened during this period has a slightly different coloration. He said the calls seemed mainly an attempt by NASA officials to find out just exactly what the Michigan group did plan to say publicly. "I think they were worried and they were trying to feel it out. I don't think I would call it overt pressuring."

Nat Cohen of NASA headquarters, who had maintained a continuing interest in the Michigan work, said: "I am not aware of any attempts to suppress that information."

Whatever the case, Cicerone and Stolarski nevertheless submitted their paper to *Science*. It was rejected. One of the reviewers recommended that it be published, but suggested that major technical improvements could be made. The second reviewer, Steve Wofsy of Harvard, recommended rejection on technical grounds, saying the authors had not provided a substantial insight into atmospheric chlorine chemistry.

This was a demoralizing period for Cicerone and Stolarski; the latter, in particular, became rather depressed. This was caused in no small part by the fact that they had received a preprint of the paper Steve Wofsy and Mike McElroy had submitted to the *Canadian Journal of Chemistry*. According to Stolarski, it did not bother him so much that the Harvard paper was mostly about chlorine, though their Kyoto talk had concentrated on NO<sub>x</sub>. Updating review papers is done all the time. What made the Michigan researchers "pretty damned mad," he said, was that the paper did not acknowledge that chlorine had been first discussed by Cicerone and Stolarski at the Kyoto meeting. Stolarski believes that McElroy should have recognized the Michigan contribution to the debate—"even if he'd spent two sentences saying our suggestion that volcanos were an important source of chlorine was hogwash."

Stolarski's reaction to this was one of withdrawal. "My initial reaction was, goddamn, let me get out of this deal. This is too much for me." He was not used to the controversy and the professional competition that characterized the stratospheric game. "I had been

<sup>2</sup> A NASA scientist who reportedly participated in this discussion said he could not recall it ever having occurred.

sheltered from that type of thing in my previous scientific work," he said. In the ionosphere, there were more scientific problems than there were people to work on them, so everyone was able to give everyone else a wide berth. Such was not the case in the crowded and highly competitive world of stratospheric research.

Cicerone remembers that Stolarski was sufficiently fed up that he was prepared to abandon the attempt to publish the paper. But Cicerone was more inclined to scrap, and he talked Stolarski into reviving the effort to publish in the *Canadian Journal of Chemistry*. Hence the call to Schiff.

Schiff was reluctant to accept the paper because the deadline had long since passed. But he felt some obligation to include Cicerone and Stolarski's work because they had, after all, been the first to raise the issue of stratospheric chlorine. So he agreed to take the paper if the publishers could handle it without delaying the publication of the journal. He also insisted that the Wofsy/McElroy paper take some notice of the Michigan work, so the Harvard paper contained a note added in the proofs that read: "After completion of this work, we learned of a discussion of atmospheric chlorine by Stolarski and Cicerone which was in part presented at the IUGG meeting in Kyoto. Their article also appears in this issue of the *Canadian Journal of Chemistry*."

The Kyoto incident left lasting scars. It generated a profound hostility between the Harvard and Michigan groups that would follow them into the fluorocarbon and fertilizer controversies that were to come.

By January 1974, NASA was taking steps to give the shuttle problem the attention it deserved. The Shuttle Exhaust Effects Panel had decided to sponsor a scientific workshop to be held at the Kennedy Space Center (KSC) in Florida. The Kyoto meeting had demonstrated that there was already a good deal of expertise on the chlorine/ozone problem within the scientific community, and the panel wanted to pick the brains of those who were active in this field of research.

One of NASA's general management review meetings was held early in December 1973. These are regular meetings at which the whole gamut of NASA activities are discussed, and Ron Greenwood

briefed NASA Administrator James Fletcher about plans for the upcoming workshop at the KSC.

It is important, in light of subsequent events, to know exactly when Fletcher really became aware of the chlorine problem. Greenwood is not convinced that his briefing really got through to Fletcher because so many things are thrown at the administrator in these meetings. Fletcher says he does not remember the briefing and wonders whether he was even there, since "generally speaking, something like that [the chlorine problem], I would notice."

The three-day workshop at the KSC started on January 21, 1974. In addition to the NASA scientists, there were about a dozen researchers from outside the agency. The discussions were highly technical, and the uncertainties were still too large to say definitely what impact the shuttle would have on the ozone layer. Rough calculations suggested the possibility of a 1 or 2 per cent ozone depletion, but at least one participant suggested that there might be a net increase in ozone.

The report that resulted from this meeting noted that the shuttle would constitute a "small but significant" addition to natural sources of HCl in the stratosphere and said that the calculations of ozone depletion ranged "from significant to insignificant."

Hal Johnston was one of those who attended the KSC meeting, and Hudson remembers that during the early part of the meeting, Johnston seemed to be going through an internal tug-of-war. "It was obvious that Harold was sitting on something that he really didn't want to sit on." Finally, about halfway through the meeting, Johnston began telling people about his discussions with Sherry Rowland concerning the fluorocarbons. The news had not yet gotten around, and Johnston was clearly concerned about the protocol of talking about it, but on the other hand, he wanted to discuss an interesting piece of new research with his colleagues. "It was interesting to see Harold break down and tell us," Hudson said.

On February 1, less than ten days after the KSC meeting NASA's physical sciences advisory committee met at NASA headquarters in Washington. A summary of the Florida workshop was one of the items on the agenda.



In theory, these meetings were, by law, open to the public. However, according to one source with an intimate knowledge of the inner workings of the space agency, NASA did everything possible to thwart the intent of the open-meeting concept and consistently tried to avoid coverage of meetings where sensitive matters that were considered "subject to misinterpretation" were on the agenda.

But NASA was not often able to shake Everly Driscoll, a former Texas high school teacher turned science writer. Driscoll's involvement with the space program had begun in 1969 when she took a job typing up the air-to-ground communications between astronaut crews and mission control for the large contingent of Japanese reporters that descended on the Johnson Space Center for the Apollo moon missions. The Japanese often had trouble following the jargon-riddled dialogue—at times it hardly qualified as English—nor could they wait for the transcripts provided by NASA, which usually ran several hours behind the events. This was not quick enough for the Japanese, who had to write their stories longhand in thin vertical columns of Japanese script, and then file by telephone. They needed someone to type up the air-to-ground communications in simple English as it was happening. Driscoll took the job and was soon a familiar sight, sitting in the Apollo press room, an earmuff-like headset on, typing quickly but calmly, surrounded by the cacophony of dozens of Japanese reporters frenziedly shouting their stories at their editors half a world away.

This was like an immersion course in the space program, and she was later able to switch to covering the moon missions as a reporter when she became space writer for *Science News*. She moved to Washington and later became science writer for the International Press Service of the U. S. Information Agency.

Driscoll regularly attended NASA's physical sciences advisory committee meetings. To her, the February 1 meeting was just one more.

During the morning of February 1, the members of the advisory committee were briefed on the result of the KSC workshop. Ich-tiaque Rasool, a high-ranking NASA scientist, discussed calculations of the amount of ozone depletion that the shuttle might cause. It appears that these numbers were in the range of 1 or 2 per cent for a global average, with an effect five times higher in the high-traffic

corridor over the Florida launch site. The numbers were quite a bit higher than any that had been previously discussed and, according to one participant, very high figures for the climatic effect of this ozone reduction were also suggested. In fact, the numbers came as a bit of a shock to those at the advisory committee meeting, most of whom had never heard them before. Though the figures were what McElroy would later refer to as "loose numbers," they nevertheless caused no small amount of consternation at the time.

The advisory committee broke for lunch, and when they reassembled after the noon period, Jim Gehrig, a staff member of the Senate Aeronautics and Space Committee, showed up. It was not long before he heard about the morning's discussion of the shuttle/chlorine problem, and he questioned McElroy, who was chairman of the session. According to Tom Donahue, who was standing beside them, McElroy was "bubbling over" about chlorine chemistry. McElroy also put in a plug for the planetary program, saying that the importance of chlorine was recognized as a result of studies of the atmosphere of Venus.<sup>3</sup>

What exactly happened next is a little unclear—remembrances are vague—but it appeared that news about the shuttle traveled quickly to Capitol Hill and discussions ensued at some point during that day between Fletcher and representatives of the Senate Space Committee. Such discussions are alluded to in a letter sent to Fletcher by space committee chairman Frank Moss dated February 1.<sup>4</sup>

Whatever happened, it produced some rather dramatic results, according to Donahue. An hour or so after the afternoon session of the advisory committee meeting got under way, McElroy, who was chairing the session, was handed a note. He looked at it and

<sup>3</sup> This was becoming an increasingly common pitch among planetary scientists as the age of relevance in research overtook the planetary program. The obvious retort of critics is that spending the money on more earthbound projects was even more likely to turn up answers relevant to this planet. In any event, neither the Michigan nor Lockheed teams, which studied the shuttle/chlorine problem nor the Rowland/Molina team, which discovered the fluorocarbon problem, had anything to do with Venus.

<sup>4</sup> The letter requested Fletcher "to provide the Committee with a full and prompt report on the nature of the problems which have been alleged to exist, your views of the validity of these concerns and actions you propose to take, including costs and schedules."

jumped up from the table. Turning to Donahue, he said: "Take over" and hurriedly left the room. The note had apparently contained an urgent summons from Fletcher, and within minutes McElroy was in the administrator's office.

Neither McElroy nor Fletcher will discuss the details of their meeting. Fletcher, in fact, said that he doesn't remember it.

However, shortly after the meeting took place, McElroy related the tale to some scientific colleagues, and according to these accounts, Fletcher was furious. He demanded to know why Mike had allowed discussion of this sensitive issue at an open meeting. In his own defense, Mike reportedly protested that the summary of the KSC meeting had been NASA's agenda item, not his.

In an interview, Fletcher acknowledged that he was concerned by the fact that the shuttle/chlorine problem had been discussed at an open meeting. He recalls the period around late January and early February as the first time he was really aware of the problem, and his concern, he said, stemmed in large part from the fact that he felt he had not been adequately briefed on the problem. "I wanted to know why people hadn't let me know about this earlier because here we have a potential environmental problem, and it didn't get into the environmental-impact statement, and how come I'm just finding out about it now? So I was a little upset with some of our guys."

Ironically enough, those who had been trying to get to Fletcher felt a sense of frustration in battling their way through the many layers of middle management. "There was a vast amount of not taking problems up to Fletcher," said one.

Fletcher himself seems to subscribe to this view: "There are a lot of things like that—that take a long time to get to the top." Yet it doesn't seem entirely fair to blame a nameless, faceless "middle management" for the failures of communication that characterized the shuttle episode. Memos were sent, briefings were held. It would appear that there was really no good reason why Fletcher should have been caught off guard by the events surrounding the advisory committee meeting in early February.

Those events could not have occurred at a worse time. It was budget time at NASA—open season on the shuttle as far as critics were concerned. In a few days, Fletcher had to appear before

the Senate Space Committee to make his annual defense of the agency's budget of over \$3 billion, and there were the usual congressional foes lurking in the wings. The shuttle was particularly vulnerable. It was NASA's most expensive project; with its annual costs mounting steadily toward the \$1 billion mark, it represented nearly a third of the space agency's entire budget.

But it was more than just the largest expenditure on the ledgers. It was also the prestige project, the inheritor of the Apollo legacy. It was, in fact, all that remained of the man-in-space program. NASA was not at all interested in a skirmish over the possible effect of the shuttle on the ozone layer, particularly with the specter of the now-defunct SST haunting them. Fletcher, who had not been head of NASA during the SST fight, says he was not worried that the shuttle would go down the drain like the SST did. But others in NASA indicate that there was certainly concern—and sometimes a fear bordering on panic—within the space agency that the shuttle might well share the SST's unhappy fate if it were to be connected, however tenuously, with the ozone controversy.

According to one source who was privy to the discussions going on in NASA at the time, there was less concern about the reaction of the space committee (which was generally sympathetic to NASA's goals) to the shuttle/chlorine problem than about press disclosure of the problem. Though Everly Driscoll was not technically a member of the press at the time—the U. S. Information Agency is a government agency—her presence at the advisory committee meeting nevertheless caused some consternation. According to one source, “once the presence of an ‘intruder’ was confirmed, a series of hurried high-level meetings was held in NASA headquarters to decide how to deal with the situation.”

Driscoll went in to see Fletcher on February 1. She is reluctant to confirm even that this meeting took place or to discuss what was said between them. However, she did acknowledge telling Fletcher that the figures for shuttle depletion of ozone—particularly the corridor effect over Florida—had alarmed her. She said that she urged Fletcher to put the problem on the public record as soon as possible.

According to other sources, Fletcher asked Driscoll to hold the story for a while to give him time to assess the situation. She reportedly agreed to hold it as long as NASA was doing something about

the problem, but in any event only unless and until someone else got wind of it. If that were to happen, Fletcher, according to these accounts, promised he would give her an exclusive interview.

Driscoll emphatically denies all of this. "He really did not ask me not to write it. If he had done that . . . that would have made me so angry that the whole story might have been different."

Fletcher's remembrances of the discussion are characteristically vague. He says he was not particularly upset about Driscoll's presence at the advisory committee meeting and he does not think he asked her to hold the story.

On February 5, four days after the advisory committee meeting, Fletcher testified before the Senate Space Committee. He did not volunteer any information about the chlorine problem, nor did the senators question him on it, even though it was clear from Moss's February 1 letter that they, or at least the chairman, already knew about the problem.<sup>5</sup>

It was at this juncture that NASA received a call from Toronto journalist Lydia Dotto, asking to speak to someone in the space agency about the shuttle/chlorine problem. Dotto was in Washington at the time on a previously planned trip related to other stories she was working on. The shuttle had not been on her agenda at all, but just before she left Toronto on February 5, she had talked briefly with Jack McConnell, a York University aeronomer who had attended the Florida meeting. McConnell was unable to say what NASA was doing by way of follow-up to the Florida meeting, so she decided to make some inquiries in Washington. Her call started a chain reaction. How had a reporter from Toronto found out about the Florida meeting? McConnell was the likely culprit. Had he gone back to Toronto and called a press conference? McConnell was also a former colleague of Mike McElroy. So Mike was once again on the spot. "I think there were some people who thought I was somewhere in the loop," he acknowledged.

What exactly transpired at this point is hard to pin down, but the

<sup>5</sup> According to an internal NASA memorandum written at the time, Fletcher met with Moss around this time and "Moss evidently told [Fletcher] not to open up to the committee on this in the next day's hearings."

result was rather dramatic. McElroy phoned McConnell in a state of great agitation, demanding to know what he had told the press. Apparently not realizing that Dotto was already in Washington, McElroy wanted to know if there was some way of heading her off, wrongly construing her trip as a direct assault on the shuttle.<sup>6</sup>

McConnell, a gentle soul, was nonplused by the fierceness of McElroy's attack. McConnell admitted that he had talked to Dotto, but defended himself by saying that no one at the KSC meeting had said anything about it being secret.

McElroy painted dire pictures of the imminent collapse of the shuttle program and said that NASA had opened "files" on McConnell and Dotto. (Interestingly enough, McElroy's *Canadian Journal of Chemistry* paper was on the verge of becoming the first paper in the open scientific literature to name the shuttle as a source of stratospheric chlorine.) Although something clearly ignited McElroy, it would appear that the intensity of his outburst stemmed more from his own gift for emotional hyperbole than from a NASA edict. No one in NASA seemed to know anything about the alleged files, and it seems doubtful that they existed. Fletcher's reaction to this episode was one of disbelief; told of McElroy's call to McConnell, he said the story must be apochryphal. "Oh you must be kidding. I don't ever do stuff like that." Asked if NASA had opened files on McConnell and Dotto, he said: "Over my dead body."

On February 14, Bob Hudson and Ron Greenwood briefed Fletcher on what had transpired at the Florida meeting. They talked to the administrator for about forty-five minutes, and Hudson got the impression that this was the first detailed scientific explanation of the chlorine problem that Fletcher had received.

Fletcher, however, says he does not remember this briefing. He recalls hearing about the Florida meeting from Ichtiaque Rasool, although Fletcher is uncertain whether this was before or after the

<sup>6</sup> Meanwhile, in Washington, Dotto was speaking with Homer Newell, one of NASA's associate administrators. He gave her a copy of the 1972 environmental-impact statement, whose only relevance to the chlorine/ozone issue was its lack of attention to the subject. As to the chlorine problem, Newell's pitch was composed in equal parts of NASA party line and bland assurances that the agency did not believe the shuttle would be a problem. But in fact, at that point, the only thing that could legitimately be said is that no one knew whether the shuttle would be a problem or not.

advisory committee meeting on February 1. He also says he does not remember either Greenwood or Hudson, two scientists who were, at the time Fletcher made this statement, in charge of NASA's stratospheric research program.

Hudson remembers that Fletcher did not seem unduly upset about the shuttle problem during the briefing, but the administrator readily agreed that there must be a program to study the problem. Shortly thereafter, a space shuttle environmental directorate was established at headquarters and an environmental-effects project office was set up at the Johnson Space Center under Bob Hudson.

Fletcher went public with the chlorine problem the day after he was briefed by Greenwood and Hudson. The occasion was a meeting of the National Space Club in Washington, where Fletcher was guest speaker. His speech was a lengthy one—a grand tour of highlights of the entire space program. Discussion of the shuttle took up only part of it, and most of that was devoted to economics. Reporting on the probable outcome of that year's budget battle, Fletcher optimistically told his audience that "we got the space shuttle over its last big hump last week."

The speech contained a few paragraphs on the shuttle's environmental impact, the last of which read:

. . . our continuing studies have shown that the hydrogen chloride in the booster exhaust may give rise to free chlorine in the stratosphere, which laboratory experiments indicate might catalyze the destruction of some stratospheric ozone. There are, however, no data to show that this actually happens and it is an extremely complicated question that we will continue to study. We fully expect that this will not turn out to be a problem but should the effects turn out to be unacceptable, there are alternative propellants that we can use in the rocket booster and we will do so.<sup>7</sup>

<sup>7</sup> Keep in mind that NASA was already committed to the \$106 million contract for the rocket boosters to Thiokol. Fletcher says that quick calculations were done just prior to his February 14 speech and NASA concluded that the economic penalty of getting out of the contract would not be "severe." NASA later estimated that the development cost for a new propellant would be around \$80 million.

This action of Fletcher's surprised some people within NASA, but his comments attracted little attention outside the space agency and virtually no media coverage.

Also on February 14, Fletcher responded to Moss's letter requesting information on the shuttle/chlorine problem. Fletcher said the matter was under study, but there was, as yet, no real proof that a problem even existed. He did not expect that NASA's studies would show the shuttle to be a danger to the environment, but he repeated his pledge that the rocket propellants would be changed if necessary. "The shuttle will be designed to have no harmful effects on the atmosphere, either in the troposphere or stratosphere." Both letters were made public during Senate hearings in late February.

In July 1977, NASA released a revised draft environmental impact statement for the shuttle. It stated that 60 shuttle launches a year would result in ozone reductions in the Northern Hemisphere of about .2 per cent, with an uncertainty of a factor of 3 in either direction. (The National Academy settled on a figure of .15 per cent ozone reduction, with a factor of 3 uncertainty. In mid-1977, the NASA figures were upped by a factor of 2 as a result of new data.) The NASA environmental impact statement also noted that the effect in the Southern Hemisphere would be smaller, by a factor of 5 to 10. According to the impact statement, the maximum impact on ozone would occur just a few years after the shuttle started injecting chlorine into the stratosphere (unlike the case of fluorocarbons, where the full impact would be delayed for a few decades). Moreover, NASA calculated that it would take only a few years for the ozone layer to recover if the shuttle booster was changed to one that did not emit chlorine. (If the boosters were changed in 1992, for example, the ozone layer would return by the year 2000 to the levels that existed in the early 1980s).

The shuttle incident was an important milestone in the ozone controversy. Just as the SST had forced scientists to consider the role of man-made  $\text{NO}_x$  in the earth's upper atmosphere, so the shuttle forced them for the first time to look at the stratospheric effect of chlorine compounds from human activities. Until the shuttle came along, the ozone-destroying capability of chlorine had been largely a textbook or laboratory curiosity.



The shuttle problem had another important effect: It injected NASA into the ozone debate in a major way. The space agency made a big play to become the "lead agency" heading the government's stratospheric research effort. Ironically enough, NASA could easily have beaten everyone else in these sweepstakes had it funded the proposal to study fluorocarbons that Charles Kolb had submitted in the fall of 1973.<sup>8</sup> But what the space agency may have lacked in foresight it more than made up in aggressiveness as it sought to convince Congress that it would be the best lead agency to run the stratospheric show.

This inspired no small amount of cynical comment. NASA had fallen on hard times since the glory days of the Apollo moon landings, and some critics saw, in many of the agency's subsequent activities, a rather desperate attempt to come to terms with the social and political climate that demanded down-to-earth relevance from NASA. But there were those who could not see an agency devoted to aeronautics and space flight as the logical choice to investigate the chemical effects of spray-can propellants on the upper atmosphere. Nor did it escape attention that, with its involvement in the shuttle, NASA had a certain vested interest in the outcome of such studies.

However, Tom Donahue said that it was he and Mike McElroy who sold NASA on the idea of going after the stratospheric research program. They had come to the conclusion that the space agency was best equipped to study the whole ozone problem, not just the fluorocarbon issue, and put this suggestion to George Low, Fletcher's deputy. They urged NASA to "take the bull by the horns." Shortly thereafter, NASA did just that.

The role of the shuttle is probably the least-known aspect of the ozone controversy. If you ask the proverbial man-on-the-street about threats to the ozone layer, he will probably mention spray

<sup>8</sup> It is also ironical that Mike McElroy, who would later figure so prominently in the fluorocarbon debate, missed this chance. Kolb told him about the fluorocarbons one evening in the fall of 1973 when the two of them happened to bump into each other at a restaurant. Kolb was anxious to have McElroy work with him on the problem but "we just never connected," said McElroy. "We got off on different tracks. There seemed to be more important things to do at the time."

cans, he may even mention SSTs, but the odds are high that he will not mention the shuttle.

In part this is because NASA, while perhaps not engaged in outright suppression, did rather successfully stage-manage a low-profile treatment of the shuttle/chlorine problem. More importantly, however, the shuttle problem was rapidly overtaken by the spray-can controversy. Fletcher went public with the shuttle problem in mid-February 1974; by June, the Rowland/Molina paper on fluorocarbons was published, and by fall, the spray-can issue had moved front and center.

There could be no low profile for the spray-can controversy. Whereas the shuttle and the SST were esoteric technologies that would never directly touch the lives of most Americans, the spray can was a ubiquitous technology familiar to all Americans. Whereas NASA had managed to keep the shuttle out of the headlines, the aerosol industry could not hope to do the same for spray cans; their only option was to meet the challenge head-on. Thus began the elaborate public-relations and advertising campaign to save the spray can.