Testimony Before Joint Hearing By Sen. Subcommittee On Science & Space And Subcommittee On Disaster Prediction & Prevention, November 10, 2005:

By Dr. Joseph H. Golden

I am honored to appear before you today in regards to Senate Bill S.517, the Weather Modification Research and Technology Transfer Authorization Act of 2005. My name is Dr. Joseph H. Golden, retired from NOAA on September 2, 2005 after 41.5 years of Federal service in NOAA, both in severe weather research and NWS operations. I now work part-time as a Senior Research Scientist in the University of Colorado's Cooperative Institute for Research in the Environmental Sciences (CIRES) in Boulder,CO. My background in weather modification research relates to the fact that I was the last NOAA manager of the Atmospheric Modification Program (AMP) in NOAA Research, until its termination by the Congress in l995. I was never asked by anyone to defend the AMP Program, based on its merits and accomplishments. The AMP program was written into NOAA's budget by the Congress for many years, beginning in the late 1970's. I view the AMP program and its research productivity as a highlight of my NOAA career, especially due to the cooperative efforts among the six States in the program (Illinois, No. Dakota, Texas, Utah, Nevada and Arizona), the universities, private-sector operators, and NOAA research. None of the NOAA AMP funds were used to conduct any operational cloud seeding, and I feel that, at this time, funding under S517 should also not be used for operational cloud seeding efforts. I am pleased to see my colleague, George Bomar here from Texas: he was one of the State program managers in AMP, and his State was the first to utilize NWS NEXRAD Doppler radar data to estimate the rainfall increases from seeding convective clouds. One of my greatest career frustrations has been witnessing the adoption of new research results and technologies we developed under AMP by other countries, while Federal research and technology transfer in my own country has largely stagnated. For example, a chemical tracer technique developed by the Nevada-AMP program to quantify the amount of snow increase due to seeding over mountains is now being used by a new cloud seeding program in Australia. In China alone, their government is funding a greatly-expanded weather modification research and operations program at $100 million per year, as well as training over 1500 new weather modification scientists.

In the limited time I speak before you today, I want to address two types of natural disasters, and the potential for planned weather modification to alleviate them: **slow-onset disasters** over many years, such as the continuing drought in the West, and the **quick-onset disasters** such as the record-breaking Atlantic hurricane season this year and the massive Oklahoma City tornado outbreak of May, l999.

Federal funding for weather modification research in the U.S. reached its pinnacle in the l970's and early l980's, and has steadily declined ever since. During its heyday, weather modification research in the U.S. was at the cutting edge of worldwide efforts. For example, NOAA conducted large-scale seeding experiments in South Florida (called FACE) and collaborated with the Navy and university scientists in Project STORMFURY, to weaken hurricanes. I participated in STORMFURY while a PhD candidate, and found it to be one of most exhilarating experiences of my career. The National Center for Atmospheric Research (NCAR) also organized the National Hail Research Experiment, which attempted to test the validity of the Russian approach to artificially reduce hail by cloud seeding. Finally, the Bureau of Reclamation carried out the High Plains experiment, to seed convective clouds for rainfall increases over the Central U.S. While each of these programs, in my opinion, produced outstanding scientific results and new operational insights, they produced results that were inconclusive insofar as *statistical evaluation* is concerned. Nevertheless, I feel that our community was a good steward and used limited funding very wisely. I am also convinced that the atmospheric sciences have come a long way during the intervening years. The scientific foundation and underlying physics in purposeful weather modification, i.e., cloud seeding, is sound and well-established. We now have both the science and the technology to launch a new research attack on some of these other vexing problems.

The need for a renewed national commitment and funding for weather modification research has become more urgent. In recent years, we have seen severe drought in my home State of Colorado and the Pacific Northwest. New research results show unmistakable impacts of air pollution in reducing seasonal precipitation over mountainous areas of the Western U.S. during the past several decades. Pollution is systematically robbing the Western mountains of winter snowpack, and if the process continues, will lead to major losses of runoff water for hydroelectric power and agricultural crop productivity. However, research in Israel has demonstrated that their long-term cloud seeding programs have offset similar pollution-induced rainfall losses in their country. The new research has also developed new analysis techniques with NOAA satellite data to objectively identify and separate pollution episodes from affected neighboring clouds. The pollution effects on natural precipitation in our country and elsewhere is certainly a critical research issue for this Bill. Another issue needing more research attention is the question of extra-area effects: if we seed cloud systems in one

area, and successfully produce increases of precipitation there, are we "robbing Peter to pay Paul" in downwind locations? Results supported by AMP suggested the answer is no, and that there is either no effect downwind, or a slight increase in precipitation.

Another weather modification research issue, and one that always elicits scientific controversy, is severe storms modification. This issue was not addressed much in the NAS/NRC weather modification report chaired by my distinguished colleague, Michael Garstang. These are the quick-onset disasters of which I spoke earlier, and include hailstorms, tornadoes and hurricanes like KATRINA and RITA this year. I should emphasize that AMP supported some outstanding hail modification research with the North Dakota Cloud Modification Program. This operational program is one of the longest-running hail suppression programs in the world. Positive results on the impact of cloud-seeding to reduce hail damage to crops, using insurance companies' records of crop-loss ratios, were so impressive, that the Canadian insurance industry has supported a new multi-year effort in the province of Alberta, Canada to protect its largest cities from hail. The Alberta hail-suppression program uses many of the techniques that we used in the AMP-North Dakota program.

After the horrendous devastation and loss of life from Hurricanes KATRINA and RITA, I have been asked several times about the possibility of hurricane modification. And while I don't have the time to fully address this issue today, I firmly believe that we are in a much better position, both with the science and the undergirding technology, than we were when Project STORMFURY was terminated in 1982. We now understand that both tornadoes and hurricanes exhibit a life-cycle, and both exhibit natural instabilities during their lifetimes. The key atmospheric condition leading to the decay of both destructive vortices is cooler, drier air, as well as cooling sea surface conditions for decaying hurricanes. Recent observational and modeling studies both suggest that there may be new approaches possible for future weakening or track-diversion of hurricanes threatening our shoreline. The key uncertainty, and one which requires enhanced observations, is more continuous and accurate monitoring of the natural fluctuations in hurricane intensity and path. For example, WILMA intensified in the western Caribbean overnight from a Category 1 to a Category 5 hurricane, resulting in the lowest pressure ever measured in the eye of an Atlantic-basin hurricane. There are now some very exciting computer models that reproduce both hurricane intensification and tornado behavior in remarkable detail. If we mount a sustained, adequately-funded national program of weather modification research and technology transfer, I believe that it may also be possible to successfully weaken tornadoes (or, alternatively, shorten their life-cycles). I would be pleased to elaborate details on promising approaches and testable hypotheses for tornado/hurricane amelioration at some future time. I am presently collaborating with w colleagues, Drs. Rosenfeld and Woodley, in testing a new technique for identifying storm systems with high threat of producing tornadoes. This technique utilizes NOAA satellite data at various wavelengths and shows promise in improving NWS lead-times for tornado watches and warnings.

Even after the demise of the AMP Program in l995, operational weather modification programs have continued to expand and flourish in the U.S. This is reflected in the annual reports of all such projects to NOAA, as required by law. Most of these projects are supported by the States, utilities or the private-sector. One of my private-sector colleagues recently noted his estimate *of total annual expenditures in the U.S. of $25-30 million* for weather modification operational projects. There is now very little Federally-supporting research to aid these operational programs in evaluation, or improving their technological base. We have some of the best cutting-edge science in NOAA research, NCAR and the universities that can help the private weather modification operators improve their evaluation of seeding effects, as well as improved targeting of seeding materials in suitable cloud systems. I like the idea of establishing the Weather Modification Advisory Board, with broad representation, which is needed to set the national agenda and priorities for these and other urgent water management issues facing the country. I have many close scientific colleagues in NOAA weather research who would welcome the opportunity to contribute to a reinvigorated national program of weather modification research and technology transfer, if support can be found. In fact, our Boulder laboratories won a Department of Commerce Gold Medal for our contributions to the recently-completed NWS Modernization and AWIPS computer workstations. I am one who has long believed, that to be successful in any form of purposeful weather modification, we must first do a very good job of predicting the natural phenomena.

In closing, I want to assure you that the U.S. has the technology and the best and brightest scientists who would welcome the opportunity to reinvigorate the weather modification field. These are very challenging issues and the worsening water crisis in the West and elsewhere demand our urgent attention.

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By Dr. Thomas P. DeFelice

I am honored to appear before you today in regards to Senate Bill S-517, the Weather Modification Research and Technology Transfer Authorization Act of 2005. My name is Dr. Thomas P. DeFelice. My background in weather modification began when I was 15 by reading books on the subject; I had many sessions with WMA forefathers Schaefer & Vonnegutt as an undergrad; my academic and subsequent professional career concentrated on learning the fundamentals of weather modification relevant sciences and its technologies; president of WMA (2000-2002), Chair WMA Public Information Committee (since 2004). I now work as the contractor program manager for 2 NOAA programs. I am here on my own behalf, expressing my own beliefs. I began this process, engaged John Leedom, who engaged Senator Hutchison & her staff, and here we are today.

Weather modification technologies are key to dealing with many present and potential future scientific, environmental, and socioeconomic issues like steadily increasing human suffering and property damage caused by hazardous weather (e.g., severe weather-Katrina, supercooled fog, freezing rain), fire, and other environmental problems related to "acid rain", biological or chemical warfare, for instance. Their application generally increases rainfall amount. Rain contributes 1% of the total global water budget. Global water consumption presently makes up 8% of the total global water budget. Models estimate about 40% of the world's population will live in water – stressed areas by the decade of the 2020's and consumption will increase. Further, air pollution (global warming) is (are) reported to reduce the amount of rainfall. Hence, a need to develop new technologies, while applying proven techniques. Water rationing and water management techniques are useful, they Do Not replenish the reduced rainwater amount. (They simply put a small band-aid on a wound that requires multiple stitches.) Therefore they fail to resolve the issues' root cause. Alternatively, weather modification technologies increase the rainfall amount (compared to normal) under certain conditions. (They simply put multiple stitches on a wound that requires multiple stitches.) Therefore weather modification technologies can resolve the issues' root cause, which *will be ensured through the research and development program set up by passing S-517 and its companion bill (HR 2995).*

Yet some retain an issue concerning whether operational cloud seeding activities, especially associated with convective clouds, achieved the intended results claimed. *Additional evaluations should pacify this issue, especially with the recent technological advances.* This would also help us answer, are weather modification technologies ready to increase water resources and alleviate, or possibly prevent, drought. *Yes they are ready to increase water resources under certain cases, based on the available 60 yr literature archive, and first hand information. S-517 provides a research and development infrastructure for a program that addresses and ultimately resolves these issues, while nurturing and developing these technologies to provide better returns on our investment.*

The *scientific* and *operational communities* generally *agree* that the recent advances in the relevant, general physical processes and technologies need to be capitalized upon in the form of a concerted and sustained national program to carry out basic and applied research in weather modification (e.g. Garstang report, Orville report, NRC). However, the *perceptions* between the science and operational communities *differ*, namely, 1) Interpretation of scientific proof, 2) Current status of cloud models as applied to weather modification, 3) Evidence of glaciogenic seeding in convective clouds, 4) Cold season orographic seeding, 5) Evidence for hail suppression, and 6) Support for specific purposes. The cold season orographic seeding perceptual difference (4) is not a significant difference in perspective, since the science community (post Garstang report) sees orographic cloud seeding as a particularly promising candidate for an intensive field program. Perceptual difference (6) reflects the differences between the individual cultures (i.e., scientific versus operational) than anything else. *Nonetheless, no implementation plans have been proposed.*

I summarize an implementation plan for S-517 for consideration by its Weather Modification Board, which addresses all issues. This implementation plan is born from sound scientific basis derived from 60 years of lessons learned exercises, recent technological advances, and science community recommendations (Garstang report, Orville report, NRC). Societal need provides an impetus for developing systems and technologies that monitor and manage atmospheric events, the creation of a new weather modification research program and implementation plan

according to standard engineering practices. *This plan helps mitigate the perceptual differences by setting up an integrated team approach to its activities, and by insisting that its research and development component be geared toward improving the effectiveness of operations.*

It calls for administering the resources and the activities for all research and development efforts directed toward optimizing the technologies used to manage atmospheric processes and their resultants (e.g., collision-coalescence, hurricanes, orographic and convective precipitation, frozen rain). Its mission would be to develop the technologies used for operational activities that help provide sustainable water supplies and reduce airborne hazards. This includes improving the understanding of the relevant processes and their simulations, as well as the evaluation methods (physical; chemical; statistical-random, non-random) for operational activities through cooperative multidisciplinary research and development arrangements and a well-designed outreach effort. Further development is needed for successful application of weather modification technologies to mitigate hurricane and tornado damage, minimize the negative affects of anthropogenic air pollution on precipitation efficiency, or to neutralize negative effects from pollutant deposition. Such requires a modeling approach, then verification, and transition to operational use.

The modern weather modification technologies applied to disperse supercooled fog, augment the ice crystal process in cloud systems, especially orographic clouds, are very effective. Statistical reanalysis using 50+ years of Sierra data show strong signals that the seeding did produce seasonal snowpack increases of 5-10%; as measured by stream runoff data (a conservative surrogate for snowpack increases). Thus, orographic systems, especially winter orographic systems, would help maximize S-517 derived program success. Garstang's report apparently was unclear on this fact.

The implementation plan does not include less developed technologies (e.g. extraterrestrial mirrors; ionization, chaos theory-related approaches; sonic initiation of precipitation, making hurricane disappear from conventional radar), or technologies whose benefits fall short of justifying their cost (e.g., using vertical pointing jet engines, or mono-layer films to suppress moisture flow into hurricanes), based on insufficient scientific and engineering test results, which pose a significant risk to programmatic success. <u>The plan does not support funding for Federal Operational cloud seeding, except for small tests/experiments of new technologies</u>.

In closing, I urge that the joint committees send S-517 to appropriate committee hearings with the companion Udall Bill (HR 2995). We have an implementation plan for the program under this bill. We have the best technology, the brightest personnel to successfully carry out the implementation plan. The 60 years scientific and engineering basis helps assure success. *Passing S-517 now, helps avert adverse effects of desertification, Katrina-like hurricane destruction, and air pollution effect on the rain process, for example. This tax payer fully supports passage of Senate Bill S-517 with a sufficient budget and duration.*

Respectfully Submitted by Tom DeFelice, PhD.