Active Experiments in Space: Past, Present and Future

Meeting summary

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The workshop ‘Active Experiments in Space: Past, Present and Future’ took place in Santa Fe, NM, on Sept. 11\textsuperscript{th}-14\textsuperscript{th} 2017. The workshop was sponsored by the Center for Non-Linear Studies and the Center for Space and Earth Science of the Los Alamos National Laboratory. The main goal of the workshop was to bring together people interested in active experiments and to connect the community of active experiments performed in the seventies and eighties with new ideas for the future. Along this line, some specific goals of the workshop were:

1. Identify the lessons learned from past (and present) active experiments.
2. Assess the current state of space-based active experiments.
3. Identify new opportunities and collaborations for future active experiments.

A total of 65 people attended the workshop, with a good mix of participants from academia and government institutions. The workshop comprised four days of talks and discussions, with 10 talks per day, including some overview talks on past active experiments. The list of submitted abstracts and most talks can be found at http://http://www.event.com/events/active-experiments-in-space-past-present-and-future/event-summary-73675ac6ba5745d48d181933c4783454.aspx.

Three audience-participation discussions centered around three questions (‘What have we learned from past active experiments?’, ‘Why are active experiments not as popular anymore?’ and ‘What is the future of active experiments?’) were important for the success of the workshop and stimulated a lot of interaction among the participants. Some of the conclusions from these discussions are summarized below.

**What have we learned from past active experiments?**

Active experiments began early in the space age, where it became clear that space was filled with plasmas and could be rather harsh to astronauts and infrastructure. When evaluating the lesson learned from past active experiments, one must keep in mind that in the early days little was known about the near-Earth environment. Active experiments were therefore designed to
understand very fundamental aspects of the space environment and its interaction with space vehicles. Nuclear weapon explosions, beams, heaters, chemical releases, water dumps, plasma plumes, tethers, antennas, and voltage biases are examples of active experiments spanning several decades of research.

Some of their most important accomplishments, highlighted by the audience, are

- Active experiments stimulated critical work in basic plasma physics: plasma waves, plasma instabilities, plasma structuring, plasma transport.
- Barium and lithium releases elucidated physical processes acting on the dynamics of plasma clouds, their interaction with ambient flows or convection, and the accompanying modifications of the magnetic fields.
- Electron-beam experiments demonstrated long-distance beam propagation, beam excitation of plasma waves, and the physics of beam-plasma discharges and these experiments led the way for studies of spacecraft charging.
- Plasma-jet experiments demonstrated the propagation of plasma streams across magnetic fields.
- The Starfish experiment demonstrated the long lifetime (years) of an artificially produced radiation belt.
- Barium releases yielded information about parallel electric fields on auroral field lines.
- Ion releases yielded information on plasma-polarization effects associated with convection.
- Ionospheric heater experiments stimulated the field of plasma-turbulence and parametric-instabilities research.

Why are active experiments not as popular anymore?

At present there are a robust number of ionospheric heating experiments at ground facilities like Haarp and Arecibo. Nevertheless, there has been a steep decline in space-based active experiments. The audience offered several reasons for this decline. First, prior active experiments, in achieving their goals, have collected most of the ‘low-hanging’ fruits. Second, in the early days of the space age there was much more ‘free energy’ available and the threshold for spacecraft reliability was lower than it is today. Third, a lot more is now known about the space environment and exploration with experiments is less needed. The second and third points imply
that, as the space community refines its scientific questions, the complexity of active experiments and their cost increases. Fourth, active experiments are typically brief and a lot of resources are spent to collect what might be a small amount of data. Fifth, the active-experiments community was not proactive in communicating the accomplishments of past active experiments. The audience discussion emphasized that the active-experiments community needs to identify the most exciting science questions that could only be answered with active experiments and make a compelling case to the rest of the scientific community. While active experiments tend to be plasma-physics experiments, the ability to broaden their scope to other areas such as astrophysics or quantum or atmospheric science and/or linking to national security applications is necessary to strengthen the case. All these aspects, combined with budgetary pressures in the space-physics community, have restricted the interest in active experiments.

**The future of active experiments?**

The workshop and the discussions conveyed a general sense of optimism for the future of active experiments. This is based on several grounds. First, active experiments have always been driven by technology and there are a lot of new technologies (metamaterials, compact relativistic electron accelerators, ELF/VLF antennas based on superparamagnetic nanoparticles, …) that are maturing and that could lead to a new era of active experiments with targeted opportunities. Second, diagnostics have improved tremendously. Coupling active experiments with better diagnostics and exploiting conjunctions with other passive systems will increase the return of active experiments enormously. In this regard, the cube-satellite program could be a path to satellite-based active experiments. Third, active experiments can and must exploit their strengths. For instance, long-range coupling (low-to-high altitude, magnetosphere-to-ionosphere) and beam or wave propagation in the near-Earth environment can only be addressed with active experiments. Last, a lot of exciting ideas for future active experiments are already being developed (for instance, CONNEX, DSX, SMART, ELF/VLF antennas based on superparamagnetic nanoparticles, …), as exemplified by the presentations given at the workshop.

In summary, while the active-experiments program that flourished a few decades ago has changed and reduced its footprint, a combination of new technologies, improved knowledge of
the near-Earth environment, better diagnostics and new ideas provides an exciting pathway for a new season of active experiments in space.

Going forward, the community of active experiments needs to further identify the most compelling questions that could uniquely be answered with active experiments, connecting to other scientific areas and to national security. Workshops, special sessions, talks and presentations are necessary to engage the broader scientific community and sponsors.