

STATEMENT OF WORK (SOW)

Sonic Boom Resistant Earthquake Warning System (SonicBREWS)

Task _____ issued under _____

1.0 Introduction / Background

According to the U.S. Geological Survey¹, USGS, "California has more than a 99% chance of having a magnitude 6.7 or larger earthquake within the next 30 years, according to scientists using a new model to determine the probability of big quakes. The likelihood of a major quake of magnitude 7.5 or greater in the next 30 years is 46%—and such a quake is most likely to occur in the southern half of the state." "For the entire California region, the fault with the highest probability of generating at least one magnitude 6.7 quake or larger is the southern San Andreas (59% in the next 30 years)."

NASA has a policy directive (NPR8710.1) to be prepared for emergencies and natural disasters, with earthquakes being the dominant cause of natural disasters for NASA Dryden Flight Research Center. The distance to the San Andreas Fault from the NASA Dryden main campus, the Dryden Aircraft Operations Facility, and the AERO Institute are about 30, 5, and 2 miles, respectively. Through this policy we are required to take action that protects lives and minimizes loss and damage to NASA resources.

Earthquake Warning Systems (EWS) are beginning to be deployed in several countries around the world, giving up to tens of seconds warning before damaging shaking begins. NASA Dryden has a desire to take advantage of these new technologies to safeguard personnel and infrastructure. Tens of seconds of warning is enough time for personnel to take refuge in place and for critical utilities and devices to be put into a more-safe mode.

Some earthquake warning systems detect strong shaking, and then transmit that information to locations further from the epicenter for their warning. Other systems take advantage of the fast traveling but not damaging P-wave, and estimates the time of arrival and intensity of the damaging S-waves, while also transmitting that information to other locations for their benefit. NASA seeks to reduce the effects of earthquake-induced hazards via a detection system that has the ability to respond and take action prior to onset of S-wave motion at the sensor site. This includes but is not necessarily restricted to systems based on P-wave detection.

Another goal of NASA is to advance the state of the art of aeronautics, including reduction in the noise levels of supersonic aircraft (i.e. sonic booms) such that civilian overland flight would be acceptable to the public. Sonic booms have been shown to create seismic motion. It is unknown, however, if sonic boom induced seismic activity would be perceived as an impending earthquake by current or future EWS. It would be

¹ <http://www.usgs.gov/newsroom/article.asp?ID=1914>, 4/14/2008

preferable to allow the development of both EWS and civilian supersonic flight without mutual interference.

2.0 Scope of Work

A research project is envisioned where seismic measurements are taken of sonic booms intended to mimic as much as possible seismic P-waves, and the results reported to the earthquake warning and supersonics communities. Some of this effort is covered under a Space Act Agreement between the Contractor and NASA.

The Contractor shall take a phased approach to gather and report on the seismic response of sonic booms and its effect on earthquake warning systems.

There will be several opportunities for measurements of sonic booms, specifically the following flight series:

- Three F-18 proficiency flights specifically to generate sonic booms. These flights can be scheduled for any time.
- Several F-18 flights for the Sonic Booms On Big Structures, SonicBOBS, Phase II program, currently scheduled for two weeks in October of 2010.
- Many F-18 flights for the Superboom Caustic Analysis and Measurement Program, SCAMP, currently scheduled for two weeks in the January to April 2011 timeframe.
- Many F-18 flights for the Waveform and Sonicboom Perception and Response, WSPR, program, currently scheduled for two weeks in the November 2011 timeframe.

The Contractor undertakes this project in part to determine susceptibility of its EWS technology to false alarms due to sonic booms, and to develop a methodology for excluding sonic booms for the purposes of earthquake warning. The research and development associated with this goal will be undertaken by the Contractor separately from this project, but may make use of the results of the project or may share the resources of the project so long as such activities do not interfere with the deliverables to Dryden. SWS reserves the right to make modifications to the seismic instrumentation with prior coordination with Dryden, so long as these modifications do not interfere with the capability of the instruments to fulfill the scientific goals of the project. During the first flight series, sonic boom detection will be provided via microphone records by Dryden. During subsequent flight series SWS may, at its sole discretion, provide sonic boom detection via its own microphone or pressure transducer instrument to be incorporated in the seismic sensor site. This will be done as part of the research and development effort to develop sonic boom exclusion for the EWS.

3.0 Tasks / Technical Requirements

Objective: Gather a database of seismic response to sonic booms and report on their effect and any mitigation required for an earthquake warning system.

3.1 Gathering of flight and seismic data

3.1.1 The Contractor shall install and operate appropriate research-quality triaxial accelerometers during NASA-provided sonic boom flights, including sensor calibrations and time-tagging.

Deliverables:

- 1) Delivery and installation of two triaxial accelerometers and one datalogger in Building 4800 on the Dryden campus by 15 September 2010.
- 2) Delivery and installation of two triaxial accelerometers and one datalogger by 31 October 2010.
- 3) Digital database of calibrated and time-tagged ground motion records of sonic boom flights, due 3 weeks after each flight series conclusion.
- 4) Digital database of calibrated and time-tagged ground motion records of earthquakes, due 1 week after each earthquake.
- 5) Raw digital data of any record requested by Dryden, due 1 week after submission of the request in writing to the Contractor.

3.2 Data analysis and draft paper

3.2.1 The Contractor shall provide monthly progress reports of the data analysis and technical paper preparation, due by the 5th of each month commencing from the conclusion of the first flight series.

3.2.2 The Contractor shall prepare an Abstract of the project for submission to one or more appropriate conferences. Conferences may include the Fall Meeting of the American Geophysical Union (December 2010 or 2011) or the Annual Meeting of the Seismological Society of America (April 2011 or 2012). Other conferences may be suggested by either party for consideration, and both parties must agree to present at each conference. Abstracts will be submitted jointly by SWS and DFRC to these conferences at an appropriate time subject to satisfactory progress on the project. The abstract submission may occur before or after completion of the technical paper. Both parties must agree to the content of each abstract submitted, no less than 14 days prior to the submission deadline.

3.2.3 The Contractor shall provide a draft of the SWS portion of the NASA/SWS co-authored technical paper due three months after the last flight series. The paper will be written in collaboration between Dryden and the Contractor, and submitted following approval by both parties.

Deliverables:

- 1) Monthly progress reports of measurements and analyses, due by the 5th of each month.
- 2) Abstract of the technical paper submitted to one or more appropriate conferences, due before the conference abstract deadline.
- 3) Draft of SWS portion of NASA/SWS co-authored technical paper due three months after last flight series.

3.3 Peer review and final technical draft of paper

3.3.1 The Contractor shall participate in peer review of the technical paper, due one month after Task 3.2.3. The peer review panel shall be convened by DFRC, and composed of professionals within the sonic boom and earthquake warning communities who are uninvolved in the project. The composition of the panel shall be determined jointly by SWS and DFRC, with DFRC selecting panelists versed in the aeronautical/sonic boom areas of the project, and SWS selecting panelists versed in the earthquake warning areas of the project. Both parties shall approve all panelists prior to the peer review.

3.3.2 The Contractor shall provide a final technical draft of the paper, due two months after the peer review. Both parties will work in good faith to submit the paper for publication in an agreed-upon peer-reviewed journal in a timely fashion after the finalization of the second draft.

Deliverables:

- 1) Participation in peer review of the technical paper, due one month after Task 3.2.3.
- 2) Final technical draft of the paper, due two months after the peer review.

3.4 Presentation of final paper

3.4.1 The Contractor shall provide presentation slides and participate in the presentation of the technical paper at a conference. The presentation at these conferences may occur before or after completion of the technical paper. Both parties must agree to the content of each presentation given at a meeting, no less than 14 days prior to the beginning of the meeting.

- 1) Participation in conference presentation of the technical paper, due at the conference presentation date.

4.0 Performance Standards, Performance Metrics, and Acceptance Criteria

4.1 **Performance Standard:** Deliverables are submitted in a timely manner.

Performance Metrics:

- **EXCEEDS:** All deliverables are complete and delivered in advance of the due date.
- **MEETS:** All deliverables are complete and delivered on the due date.
- **FAILS:** At least one deliverable is not complete or delivered on the due date.

4.2 **Performance Standard:** Required monthly status reporting is complete, understandable, and provided on the due date.

Performance Metrics:

- **EXCEEDS:** Monthly status reporting is error free, complete, and provided before the due date.
- **MEETS:** Monthly status reporting is complete with only minor errors and provided on the due date.
- **FAILS:** One or more required monthly status reports are not available, or errors are noted or provided after the due date.

4.3 **Performance Standard:** Product quality meets customer's documented requirements and expectations.

Performance Metrics:

- **EXCEEDS:** Product quality exceeds customer's documented requirements and expectations. Customer provides written or verbal communication indicating the same.
- **MEETS:** The product quality is as documented in the requirements and meets documented customer expectations. Customer is satisfied with product and can use in the manner intended.
- **FAILS:** Product does not meet documented requirements or customer expectations. Customer is not satisfied with product and cannot use in the manner intended.

4.4 **Performance Standard:** The Contractor delivers product within schedule.

Performance Metrics:

- **EXCEEDS:** The Contractor delivers product to the customer prior to scheduled delivery date.
- **MEETS:** The Contractor delivers product to the customer on scheduled delivery date.
- **FAILS:** The Contractor delivers product to the customer after scheduled delivery date.

4.5 Acceptance Criteria: Acceptance of a deliverable is determined by the Contracting Officer assessing that the deliverable complies with the terms and conditions of the task order and/or contract.

5.0 Government Furnished Information & Services

The Government will provide the following to the Contractor (as given by the associated Space Act Agreement):

1. F-18 generated sonic booms.
2. Operation of sonic boom ground transducers, data acquisition systems, and meteorological systems.
3. Coordination of flight planning.
4. Field personnel during flights to operate Government provided field equipment.
5. Technical paper text and graphics to adequately describe the sonic booms and flights flown.