Below are the abstracts of proposals selected for funding for the LARS program. Principal Investigator (PI) name, institution, and proposal title are also included. Eighteen proposals were received in response to this opportunity. On February 1, 2016, 8 proposals were selected for funding.

**Marc Caffee/Purdue University**  
**Radionuclides as Probes of Solar System Processes: Development of AMS Techniques for their Measurement in Returned Samples**

This proposal seeks funding to continue the development of AMS measurement capabilities at the Purdue University AMS facility. The goals are to lower the detection limits for those nuclides we commonly measure, $^{10}$Be, $^{26}$Al, $^{36}$Cl, and $^{129}$I, and to develop techniques for nuclides that we presently cannot measure in extra-terrestrial samples, $^{53}$Mn and $^{41}$Ca.

Under previous SRLIDAP funding we purchased, installed, tested, and are now using a new beam-line that has a gas-filled-magnet (GFM) for separating isobaric interferences. We have demonstrated that the beam-line and the GFM work as anticipated for $^{26}$Al, the radionuclide that represented the first test of its capabilities. We have also demonstrated that the GFM separates the $^{10}$B isobar from $^{10}$Be more effectively than simply ranging out the $^{10}$Be in foils or thin gas cells; the GFM is now used for all $^{10}$Be measurements. The GFM successfully separates $^{36}$S from $^{36}$Cl, allowing routine measurements of $^{36}$Cl. The work to be done under the auspices of this proposal encompasses three tasks: 1) constructing a new dE/dx detector optimized for the GFM; 2) developing the AMS techniques for measuring $^{53}$Mn; and 3) using an ion source test bed to optimize negative ion extraction efficiency for all measured cosmogenic nuclides.

The successful measurement of radionuclides in extraterrestrial samples returned by spacecraft requires continuing improvements in detection sensitivity. Small samples (Hayabusa and future missions such as Hayabusa-2 or OSIRIS-Rex) or small concentrations (Genesis) require ultra-sensitive detection sensitivity. Successful implementation of the proposed instrumentation will reduce interfering backgrounds, decrease required sample sizes of routinely measured radionuclides, and enable new measurement capabilities.

The work is relevant to a wide variety of NASA’s goals as stated in the ROSES-2014 NRA. The solicitation for LARS states Proposals solicited under this program are expected to include those that seek to develop new analytical instrumentation or combinations of analytical instruments, or new components of analytical instruments, leading to significant improvements in the precision, resolution, or sensitivity of...
measurements compared to the existing state of the art. The NRA also states that of interest are proposals that will push the limits of current technology, for example by elimination of analytical interferences of contamination problems. Continued development of the gas-filled magnet in particular is aimed at elimination interferences that cannot be eliminated by chemical preparation.

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**Denton Ebel/American Museum of Natural History**

**Non-destructive Analysis of Comet Grains and Tracks: Minerals and Original Grain Properties**

We propose to use three non-destructive 3-dimensional (3D) imaging and analysis techniques to discover new comet grains, learn their mineral identities, and decipher their histories. Analysis of whole comet grain tracks in aerogel will be used to infer the original properties of grains before their 6.1 km/sec impact into the aerogel capture medium used by the Stardust mission. We have developed expertise in using a laser scanning confocal microscope (LCSM) to obtain high resolution 74 nm by 74 nm (x and y) by <370 nm (on optic axis z) resolution 3D images, in multiple wavelengths, of particle tracks in "keystones" cut from the aerogel capture tiles. We have greatly improved our ability to better resolve individual features in particle tracks by improving deconvolution technique to remove distortions which are inherent in this kind of optical microscopy. We will combine LCSM maps with stereo X-ray fluorescence chemical mapping (S-XRF) at ~2 microns/pixel performed at the Advanced Photon Source synchrotron, a Department of Energy user facility. We have developed stereo S-XRF imaging methods to identify non-cometary dust contaminants on keystone surfaces, and to match up chemical signatures (S-XRF spectra) with specific particles in the 3D LSCM data.

The third technique, which we will develop during the proposed grant cycle, is laser Raman microscopy coupled with the imaging ability of the LSCM. We were selected in the ROSES 2013 cycle and have installed a Raman spectrometer on our LSCM bench. We got first light (spectra) on this instrument in April 2015. We expect to be able to switch between reflectance imaging mode and the Raman spectrometer without changing focus, and to be able to distinguish between broad classes of grains: metal, sulfide, silicate, and Ca-, Al-, REE-rich "CAI-like" grains. This will offer advantages over S-XRF, for which beamtime is highly competitive. We intend to draw on the experience of our collaborators (Rossman, Zolensky, Harlow) in Raman and other spectroscopies. We have established by preliminary Raman work (by Rossman) on basalt-shot aerogel that fluorescence is not a killer in using Raman on these samples. Colleagues in England have proved proof of concept using Raman on aerogel keystones, although with much lower spatial resolution than ours. We are highly cognizant that we must thoroughly test this instrument on lab analogs and minimize power so that our analysis does not alter either minerals or organic material in the comet tracks. A primary goal is to discover potentially important comet grains so that their extraction and mounting can be requested by collaborator Davis at the University of Chicago for analysis with nanometer-scale
analytical facilities. Our ability to provide extremely detailed 3D information on grain locations is an important part of this goal.

A further goal is to develop our ability to model the physics of hypervelocity impacts into aerogel so that the original properties (mass, porosity) of impacting cometary particles might be inferred. We have obtained the hydrodynamic codes CTH and iSALE, and we will work with collaborator Melosh's group to develop an equation of state for silica aerogel. Both CTH and iSALE are codes used within the impact modeling community for problems similar to the Stardust hypervelocity impact scenario.

Upon completion of work, we will disseminate our results to the scientific community through peer-reviewed publications, and to the public through presentations and museum-based informal education. We will archive all our results at AMNH and provide them to JSC Curation as appropriate. This work will address the LARS goal, to "maximize the scientific return from the samples provided by missions such as Stardust, through development of ... advanced analytical techniques required for the complete analyses of the samples". It will "contribute to the development of future missions" that might use aerogel capture.

Steven Jones/Jet Propulsion Laboratory
Hypervelocity capture and analyses of comet Wild 2 analog particles based on Stardust samples

The scientific objective of this proposal is to make observations as to how hypervelocity capture in gradient silica aerogel, like that experienced by cometary dust from Wild 2 during the sample collection by the Stardust instrument, alters olivine, pyroxene and Fe (Ni) sulfides and amorphous glass embedded with metals and sulfides (GEMS). Light gas gun impact tests using 1 to 20 micron projectiles at velocities of between 2 and 6 km/s. Raman spectroscopy, synchrotron x-ray microprobe, scanning electron microscopy, and transmission electron microscopy will be used to answer the following primary questions: 1) Does hypervelocity capture in aerogel favor the survival of olivine over pyroxene? 2) Are silicate mineral compositions altered during capture? 3) Do crystalline silicates melted form amorphous silicates? 4) Do metal sulfides lose sulfur during capture? 5) Are GEMS-like materials formed by hypervelocity capture of metal sulfide aggregates and under what conditions can this occur? and 6) Are GEMS altered during capture, and if so, how are they altered?

The primary technical objective of this study is to mimic as closely as possible the particles and the aerogel involved in the Stardust sample capture in ground based experiments. While light gas gun experiments have involved the capture of olivines and pyroxenes, typically the particles were large (100 microns) and the aerogel was relatively dense. Here the particles will be small (5 - 10 microns) and the aerogel will be Stardust gradient density. It has become apparent that terminal particles are altered much less than particle grains found in the track bulb. This study will also impact test aggregates with
known grains in them. Aggregates will be produced that contain a known olivine, pyroxene, or metal sulfide. Therefore, a study can be done of the difference in capture alteration between terminal particles and grains in the track bulb. Since a great deal of the material collected by the Stardust aerogel collectors was captured in the bulbs of Type B capture tracks, the better understanding researchers have of how these materials may have been altered the greater the scientific return from the mission.

The fact that the projectiles used in this study will be much better analogs (size, composition) to the fine particles captured by the Stardust collector than those used in previous studies and that the aerogel used here will have the same density gradient (12 mg/cc to 50 mg/cc) to that used in the Stardust collector, means that the data collected in this study will be significantly more relevant to the analyses of the Stardust return samples. Since the ways in which captured particles are altered during capture depends greatly on the size of the particles, conducting tests with projectiles are comparable in size to those captured by Stardust is important. These results will provide a much better understanding of how small particles are altered when captured in aerogel.

Noriko Kita/University Of Wisconsin, Madison

Oxygen and magnesium isotope studies of Wild 2 particles and their origins in the early solar system

We propose to obtain high precision oxygen and magnesium isotope analyses of particles recovered from the comet 81P/Wild 2 (Stardust Mission) using a secondary ion mass spectrometer IMS 1280 at University of Wisconsin (WisSIMS) in order to understand the origin of the particles in the early solar system. A relationship between oxygen isotope ratios and Mg# = molar MgO/(MgO+Fe)% of olivine and pyroxene is indicative to their formation environments and isotope reservoirs and provide a clue to the location where they formed in the protoplanetary disk. Magnesium isotopes provide chronology of particles through the decay of 26Al to daughter 26Mg (half life of 0.7 million years) and/or evidence of high temperature processes between solid and gas (evaporation and condensation) as stable isotope fractionation. Detailed isotope studies combined with mineralogy and chemistry will be a key to understand how these high temperature particles formed and were transported to comet forming regions.

We plan to analyze relatively larger (e a few µm) crystalline silicates using ~2µm SIMS spot size. Particles are selected according to the mineralogy and major element chemistry that are obtained from the microtome TEM sections by Collaborators Brownlee and Joswiak (U. Washington) and Zolensky (NASA JSC). We focus on high Mg# olivine and pyroxene, which are known to be either chondrule-like objects or condensates of the early solar system, such as LIME (low-iron, manganese-enriched) olivine. Magnesium isotope analyses will be performed all particles that show 16O-rich isotope signatures and those containing Al-rich phases larger than 3µm in size.
We propose to acquire new oxygen primary ion source of the IMS 1280 (RF Plasma source) that will provide higher primary beam intensity for small spot sizes at least 10 times or even higher than that of current ion source. The higher primary beam intensity will improve secondary ion intensities, which results in improvements in analytical precisions.

Results obtained from the proposed studies will maximize scientific return from the samples provided by Stardust Mission and advance our knowledge of the early evolution of Solar System, which could not be obtained solely from studies of primitive meteorites. Analytical techniques established in the proposed research will benefit the analysis of meteorites, interplanetary dust particles, and samples from future planetary return missions.

James Lyons/Arizona State University
Ion microprobe analysis of oxygen isotopes in Earth's upper atmosphere from LDEF targets, and relevance for Mars upper atmosphere

NASA Laboratory Analysis of Returned Samples Step 1 proposal (2015)

Title: Ion microprobe analysis of oxygen isotopes in Earth's upper atmosphere from LDEF targets, and relevance for Mars upper atmosphere

PI: James Lyons, ASU; Collaborator: Kevin McKeegan, UCLA

Introduction: The Long Duration Exposure Facility (LDEF) was launched into low Earth orbit in 1984, and retrieved in 1990 by Columbia. The nominal orbit was ~480 km, but over the course of the extended mission, the orbit decayed to 330 km. A suite of targets were placed at various locations on LDEF to assess and collect impacting IDPs. In addition to collecting IDPs, targets on the leading edge of the spacecraft also impacted Earth's upper atmosphere at an orbital velocity ~ 8 km/s. Here we propose to use depth profiling by ion microprobe to measure the oxygen isotope composition of Earth's upper atmosphere. The oxygen composition of the upper atmosphere is primarily O atoms and O+ ions. These highly reactive species become implanted in the target surface and possibly replace O in any target oxide layer present at launch. Preliminary nanosims data obtained at Washington University for an LDEF Al target (from a region of the target with no IDP impacts) reveal delta18O ~ -200 to -300 0 relative to SMOW. Such a large depletion in 18O is consistent with diffusive separation of O isotopes above the terrestrial homopause (~100 km). The noise level of these measurements was high due to the low count rates. We expect that the higher count rates from the ion microprobe will yield better signal to noise. In addition to determining the oxygen isotope composition of Earth's upper atmosphere, this work may have implications for escape of oxygen from Mars. The NASA MAVEN mission is currently in orbit at Mars, and will in the near future make measurements of oxygen (and other) isotopes in the upper atmosphere. The
analyses proposed here offer the possibility of a direct comparison of upper atmospheric oxygen isotopes for the two planets.

Proposed research:
1. Ion microprobe measurements of O isotopes from LDEF Al targets. Preliminary nanosims data on one Al target already demonstrates that a large isotope fractionation is measurable in LDEF targets. Our first objective will be to analyze ~ 10 Al targets, all from the leading edge of the spacecraft. We presently have 3 targets, and will request 7 more from NASA JSC.
2. Ion microprobe measurements on other LDEF targets. We also have ~ 10 Ge targets, and one Au target. We will analyze these for O isotope composition. More Au targets will be requested form JSC if we see an interesting isotope signature. The lack of an oxide layer in the Au targets may make analysis of them difficult or impossible, since the penetration depth of 8 km/s O atoms is expected to be very shallow.
3. Modeling of results and implications for Mars. Although the focus of this proposal is on the measurements from the LDEF targets, we will interpret the results using an atmospheric model that includes diffusive separation, and we will apply the results to a similar model for Mars for comparison with eventual MAVEN data.

**Kunihiko Nishiizumi/University of California, Berkeley**

**Measurement of Cosmogenic Radionuclides in a Microgram of Hayabusa Samples**

Our goal is to understand the surface history and characterization of the asteroid 25143 Itokawa by study of returned samples from the Hayabusa mission. We investigate and utilize radionuclides (10Be, 26Al, 36Cl, and 53Mn) produced by cosmic rays (both solar and galactic cosmic rays). Expected maximum cosmogenic nuclide concentrations in a microgram (~100 µm in diameter) of Hayabusa sample are a few times $10^4 - 10^5$ atoms or lower. These values are close to or lower than the present best detection limits of highly sensitive accelerator mass spectrometry (AMS). Although we have performed the most sensitive measurements of 10Be and 26Al in the smallest extraterrestrial (Hayabusa) sample ever done, we encountered issues that require further development of both chemical laboratory techniques and improvements in AMS measurements. Our work for the next three years includes: (1) measurements of cosmogenic nuclide in samples even smaller than those recently measured facilitated by the successful development of clean chemical separation procedures, including making new ultra-pure chemical carriers; (2) measurements of cosmogenic radionuclides and major elements in a set of ~ microgram sized Hayabusa samples using AMS and ICP-MS; and (3) measurements of cosmogenic radionuclides in a microgram level of lunar grains to enable interpretation of the measured cosmogenic nuclides in the Hayabusa samples, most notably the already noted wide scatter of cosmogenic noble gas concentrations in individual Hayabusa grains, which correspond to surface exposure ages of 1 - 20 Myr. The development techniques and methods will be applied not only for Hayabusa samples but also for future sample return missions such as Hayabusa-2, OSIRIS-Rex, or Mars sample return and for measurements of cosmogenic nuclides in IDP’s. The described research is directly
relevant to NASA Laboratory Analysis of Returned Samples (LARS) program in ROSES-2015. These include maximize the scientific return from the samples provided by missions such as Hayabusa, through development of advanced analytical techniques required for the complete analyses of the samples they return, and analytical work on samples returned by Hayabusa. The proposed research to undertake detailed and quantitative studies of the cosmic ray exposure record and evolution history of solar system materials is highly relevant to several goals of the most recent NASA Strategic Plan 2014 and the Science Plan 2014 for NASA’s Science Mission Directorate (SMD).

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Mukul Sharma/Dartmouth College

Determination of osmium concentration and isotope composition of Solar Corona using Genesis samples

Science Objective: Our primary goal is to evaluate the solar osmium (Os) abundance as well as solar 187Os/188Os ratio and to compare them with chondrites. The Os concentration of solar corona is not accurately known; however, the first ionization potential (FIP) of Os is 8.7 eV, suggesting that Os in the solar wind will be unfractionated from other low-FIP elements in the solar photosphere (e.g., [1]). The 187Re-187Os isotope system (187Re--->187Os, t1/2 = 41.2 billion years) has been extensively utilized in assessing the evolution of the planetary mantles (see e.g., [2-4]) with the assumption that the Os isotope composition of solar nebula was homogeneous [5] and that chondritic 187Re/188Os (= 0.40186) and 187Os/188Os (= 0.126) are identical to that of the sun. We will analyze samples obtained from Genesis mission to test these assumptions. In addition, our method of Os analysis will leave us with dissolved Genesis material from which we hope to measure other Pt-group elements.

Methodology: At Dartmouth we have developed extremely low-blank, high-sensitivity methods to measure Os concentration and isotope composition using negative thermal ionization mass spectrometry. These techniques will be combined with the latest multiple-ion counting in collaboration with Thermo Fisher Scientific (Germany) to obtain precise Os abundance and isotope composition of solar wind Os separated from ~2.4 cm2 fragments of a Genesis silicon collector. At a 2-year Genesis array fluence of 1.3 million Os atoms/cm2, an area of ~2.4 cm2 is equivalent to ~3 million atoms or about 1 femtogram of Os. Several small broken up pieces of silicon collector (each with an area of ~25 mm2) will be cleaned by implementing and refining extant aqua-regia based cleaning and HF+HNO3 based silicon etching protocols. Our high purity reagents and method of Os analysis will leave us with dissolved Genesis material from which other elements (e.g., Ba, Nd, Pb) could potentially be analyzed. If our lab blanks and sensitivities are found insufficient for work beyond Os, we will make these samples available to other Genesis PI’s.

Relevance: This unique work addresses Genesis objective #13 and #17 (measuring Pt group elements, comparing solar composition with CI, respectively). More importantly, it
Igor Veryovkin/University of Illinois at Chicago
Determination of Trace Element Abundances in Genesis Solar Wind Collectors by Resonance Ionization Mass Spectrometry

One of the most critical questions in planetary sciences is how the Solar System evolved from a nebula of interstellar gas and dust into planets, moons and asteroids, all with markedly different compositions. To advance our understanding of Solar System formation, the NASA Genesis mission has collected samples of the solar material, represented by the Solar Wind (SW), and returned them for analyses in terrestrial laboratories. This project addresses two main goals of the NASA LARS Program, the development of instrumentation and methodology for analyses of Genesis SW samples and their application to actual analyses by Resonance Ionization Mass Spectrometry (RIMS).

The scientific objective of this project is to perform such analyses for SW Mg, Se, Sr, Rb, Zr, and Y. SW Mg will be measured as a reference for comparison with other trace SW elements. Analyses for Se, Sr and Rb will aim at improved understanding of non-volatile/volatile element fractionation in the early solar nebula and testing the idea of preferential accretion of gas or dust by the Sun. To this end, the abundances of Kr will be obtained by interpolation from abundances of the neighboring elements (Se, Sr and Rb) measured by RIMS and compared to actual abundances of SW Kr measured by others and corrected for first ionization potential fractionation. If, e.g., the measured Kr abundance is higher than the interpolated Kr abundance, this would be evidence that the Sun preferentially accreted volatiles, possibly due to formation of outer solar system planetesimals. Analyses for Zr and Y will aim at re-initiating a discussion of why the clear r- and s-process double peak structure in the Solar System element abundance curve associated with the magic neutron numbers N=82 and N=126 is not apparent for the N=50 region.

The technical objective of this project is to enable such analyses by major improvement of RIMS instrumentation. To this end, an existing time-of-flight mass spectrometry instrument in UIC Department of Chemistry will be upgraded with RIMS capability and new ion optics enabling high sensitivity analyses with high mass resolution. We will take advantage of two new approaches developed by the PI of this project earlier to enable reproducible quantitative analyses despite severe contamination of the Genesis samples: the Gentle Dual Beam depth profiling technique applicable to Si and DOS collectors and dry chemical etching of DOS collectors with XeF2 for backside depth profiling. Also, a Planetary Major Equipment Request will be attached to this project to implement the major instrumental upgrades needed for improving data quality, as follows. On the Mass Spectrometry side, (1) signal-to-noise ratios will be significantly improved - by modifying ion optics to more efficiently suppress secondary ions and to operate in
orthogonal acceleration regime, thus creating two-stage noise filtering. (2) quality and reproducibility of depth profiling on both front and back sides of the SW collectors will be significantly improved as well - by installing brighter ion sources with enhanced stigmatic focusing capabilities and higher current output. This will also reduce the sample consumption and significantly shorten the overall analysis time. On the Resonance Ionization side, efficiency of the ionization will be significantly improved by implementing a new intra-cavity photo-ionization approach.