



### **Cryogenic Liquid Sample Acquisition System for Remote Space Applications**

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There is a need to acquire autonomously cryogenic hydrocarbon liquid sample from remote planetary locations such as the lakes of Titan for instruments such as mass spectrometers. There are several problems that had to be solved relative to collecting the right amount of cryogenic liquid sample into a warmer spacecraft, such as not allowing the sample to boil off or fractionate too early; controlling the intermediate and final pressures within carefully designed volumes; designing for various particulates and viscosities; designing to thermal, mass, and power-limited spacecraft interfaces; and reducing risk. Prior art inlets for similar instruments in spaceflight were designed primarily for

atmospheric gas sampling and are not useful for this front-end application.

These cryogenic liquid sample acquisition system designs for remote space applications allow for remote, autonomous, controlled sample collections of a range of challenging cryogenic sample types. The design can control the size of the sample, prevent fractionation, control pressures at various stages, and allow for various liquid sample levels. It is capable of collecting repeated samples autonomously in difficult low-temperature conditions often found in planetary missions. It is capable of collecting samples for use by instruments from difficult sample types such as cryogenic hydrocarbon (methane, ethane,

and propane) mixtures with solid particulates such as found on Titan. The design with a warm actuated valve is compatible with various spacecraft thermal and structural interfaces.

The design uses controlled volumes, heaters, inlet and vent tubes, a cryogenic valve seat, inlet screens, temperature and cryogenic liquid sensors, seals, and vents to accomplish its task.

*This work was done by Paul Mahaffy, Melissa Trainer, Don Wegel, Douglas Hawk, Tony Melek, Christopher Johnson, Michael Amato, and John Galloway of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-16510-1*

### **Spatial Statistical Data Fusion (SSDF)**

**The approach models the spatial covariance function of the underlying geophysical field using linear combinations of multi-resolution spatial basis functions of low dimensionality.**

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As remote sensing for scientific purposes has transitioned from an experimental technology to an operational one, the selection of instruments has become more coordinated, so that the scientific community can exploit complementary measurements. However, technological and scientific heterogeneity across devices means that the statistical characteristics of the data they collect are different. The challenge addressed here is how to combine heterogeneous remote sensing data sets in a way that yields optimal statistical estimates of the underlying geophysical field, and provides rigorous uncertainty measures for those estimates. Different remote sensing data sets may have different spatial resolutions, different measurement error biases and variances, and other disparate characteristics.

A state-of-the-art spatial statistical model was used to relate the true, but

not directly observed, geophysical field to noisy, spatial aggregates observed by remote sensing instruments. The spatial covariances of the true field and the covariances of the true field with the observations were modeled. The observations are spatial averages of the true field values, over pixels, with different measurement noise superimposed. A kriging framework is used to infer optimal (minimum mean squared error and unbiased) estimates of the true field at point locations from pixel-level, noisy observations.

A key feature of the spatial statistical model is the spatial mixed effects model that underlies it. The approach models the spatial covariance function of the underlying field using linear combinations of basis functions of fixed size. Approaches based on kriging require the inversion of very large spatial covariance matrices, and this is usually done by making simplifying assumptions about

spatial covariance structure that simply do not hold for geophysical variables. In contrast, this method does not require these assumptions, and is also computationally much faster. This method is fundamentally different than other approaches to data fusion for remote sensing data because it is inferential rather than merely descriptive. All approaches combine data in a way that minimizes some specified loss function. Most of these are more or less ad hoc criteria based on what looks good to the eye, or some criteria that relate only to the data at hand.

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