**Custom SHARAD processing via the CO-SHARPS Processing Boutique.** N. E. Putzig[1,†], R. J. Phillips[1], B. A. Campbell[2], J. J. Plaut[3], J. W. Holt[4], F. Bernardini[1], A. F. Egan[1] and I. B. Smith[1]. [1]Southwest Research Institute, Boulder, CO; [2]Smithsonian Institution, Washington, DC; [3]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA; [4]Institute for Geophysics, University of Texas, Austin, TX. [†]Email: nathaniel@putzig.com.

**Introduction:** Prior to the orbit insertion of the Mars Reconnaissance Orbiter in 2006, the Shallow Radar (SHARAD) Team developed software to apply a standard set of radar processing parameters to the data, which was implemented at the SHARAD Operations Center (SHOC) in Rome and included delivery of products to NASA's Planetary Data System (PDS) [1]. At the same time, U.S. members of the SHARAD Team identified the need for custom processing capabilities, and they developed alternative software for that purpose. Early in the mission, the team built a web-based interface to the U.S. processing code and products that allows users to choose and apply a range of parameters for two different radar processors and a clutter simulator. The U.S. processors and web interface are currently installed at the Southwest Research Institute's Boulder office and are collectively referred to as the Colorado Shallow Radar Processing System, or CO-SHARPS. In 2014, access to the CO-SHARPS Processing Boutique was opened up to individuals outside of the SHARAD Team.

**SHARAD Processors:** The Italian SHOC processor uses a fixed set of parameters to produce standard SHARAD radargrams, including the summing of raw radar pulses to produce an along-track frame interval of 300 m and Hann weighting to suppress sidelobes [1]. Focusing and mitigation of ionospheric distortion effects is achieved using a phase-gradient autofocus algorithm [2].

The focused processor developed by the Smithsonian Institution (SI) [3] sums raw radar pulses to a fixed output frame interval matched to the grid spacing of the Mars Orbiter Laser Altimeter (MOLA) global elevation map (128 ppd, ~460 m [4]). Users may choose from four weighting methods to trade between sidelobe suppression and vertical resolution, set focusing apertures between 256 and 3072 frames, and adjust the multilook bandwidth. Optionally, users may also choose to create ground-track maps and unfocused radargrams. The SI processor uses an image-optimization autofocusing technique [3]. In 2014, SI began delivery of a standard set of products to the PDS that supplements the Italian deliveries [5].

The focused processor developed by the Jet Propulsion Laboratory (JPL) allows users to specify the summing of raw frames, which establishes the output frame interval [6]. Range-compression weighting may be set to either Hann or uniform, and the aperture is fixed at 4096 raw frames. The JPL processor employs the Chapman model for correction of ionospheric phase distortion and an omega-K focusing algorithm [7], and it also provides for the generation of depth-converted radargrams by specifying a dielectric permittivity to use below the MOLA-predicted surface return.

To aid the interpretation of radargrams, the University of Texas (UT) developed a incoherent facet-based clutter simulator that enables one to distinguish off-nadir surface returns from likely subsurface returns in radargrams [8]. The simulator determines surface facets from a digital elevation model (DEM) along the ground track for single SHARAD observations. The UT simulator at CO-SHARPS uses MOLA DEMs, and users may run it in tandem with the JPL processor.

**Web Interface:** Access to CO-SHARPS requires user authentication via secure shell. New users may request an account from the web page at http://boulder.swri.edu/sharad.php. Upon receiving access credentials and logging into the CO-SHARPS web interface, users will be presented with a menu that includes links to the CO-SHARPS Processing Boutique and the SHARAD PDS site for reference. Within the Processing Boutique, users may specify the processor and pa-

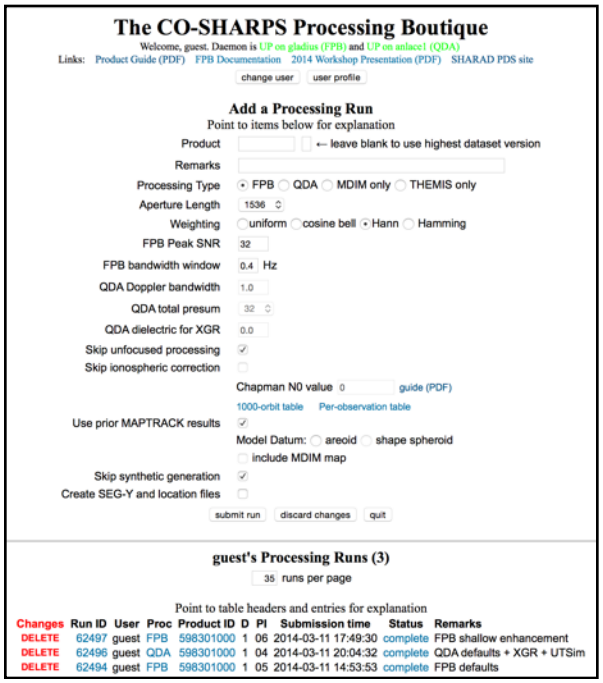


*Figure 1. Web interface to the Processing Boutique allows users to specify processor type and adjust parameters (top). A table (bottom) shows status of user runs, with links to output products.*

rameters to use for custom processing of individual SHARAD observations (Fig. 1). Processing jobs are queued to a back-end system, with status displayed in a table on the front-end web interface. Upon completion, links are provided to access output radargrams and ancillary products (ground-track maps, log files, etc.).

**Example Products:** Custom parameterization of SHARAD processing allows users to examine different aspects of the data that may not be evident in the standard products (Italian and U.S.) that are available from the PDS. For example, if one wishes to enhance shallow returns in polar layered deposits, choosing a shorter aperture, uniform weighting (at the expense of allowing stronger sidelobe energy), and a broader-bandwidth multilook window (Fig. 2) may achieve a more desirable result, depending on the aims of the study.

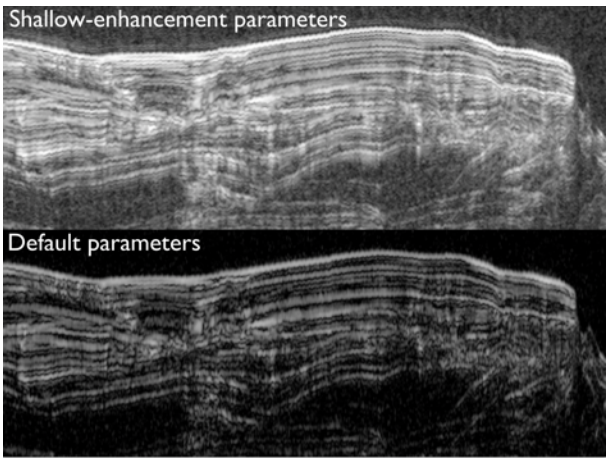


*Figure 2. Segment of SHARAD radargram 5983-01 over polar layered deposits with standard (bottom) and custom (top) SI processing parameters. Enhancement of finer shallow layering is evident in the upper panel. Custom (default) parameters are: aperture of 1024 (2048) frames, uniform (Hann) weighting, and a multilook bandwidth of 0.8 (0.2) Hz. Segment spans ~170 km and ~10 µs of delay time (~1 km depth).*

With the JPL processor, CO-SHARPS provides a different set of configurable parameters that allow users to examine the effects of changing the Doppler bandwidth and the along-track summing of frames, and the co-aligned UT simulator output enables a careful analysis of clutter (Fig. 3). The depth conversion capability also provides a means to correct the vertical geometric distortion of subsurface structures due to topography and examine alternative compositional scenarios for subsurface materials.

**References:** [1] Slavney S., Orosei R. 2007, *MRO SHARAD Reduced Data Record Software Interface Specification v1.0,* PDS Geosciences Node. [2] Eichel P.H., Jakowatz Jr. C.V. Jr. 1989, *Optics Lett. 14*, 1101–1103. [3] Campbell B.A. et al. 2011, *IEEE Geosci. Remote Sens. Lett. 8(5)*, 939–942. [4] Smith D.E. et al. 2001, JGR 106, 23,689–23,722. [5] Campbell B.A. 2014, *U.S. SHARAD Data Product Description for the PDS v2.1,* PDS Geosciences Node. [6] Safaeinili reference? [7] Cumming I.G., Wong F.H. 2005, *Digital Processing of Synthetic Aperture Radar,* Ch. 8, Artech House, Boston. [8] Holt J.W. et al. 2006, *JGR 111,* E06S24.

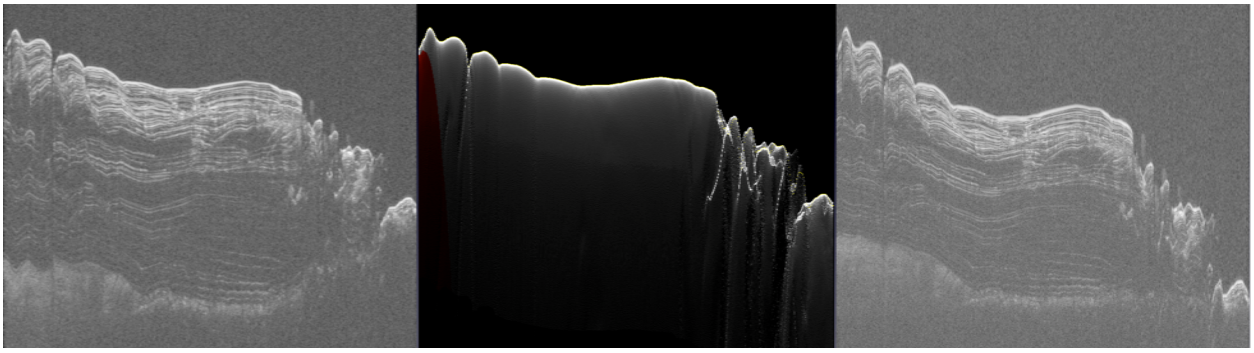

*Figure 3. SHARAD radargram 5983-01 with default JPL processing parameters shown in delay time (left) and depth converted assuming water-ice properties (right). Center panel is a UT clutter simulation in delay time. Where troughs are crossed obliquely, significant clutter occurs at delays greater than that of the surface return, with some corresponding features visible in the radargram. Spans ~600 km, with center image surface-to-base ~20 µs of delay time or ~2 km thick.*