An *In Situ* Automated Rock Thin Section Instrument

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Overview

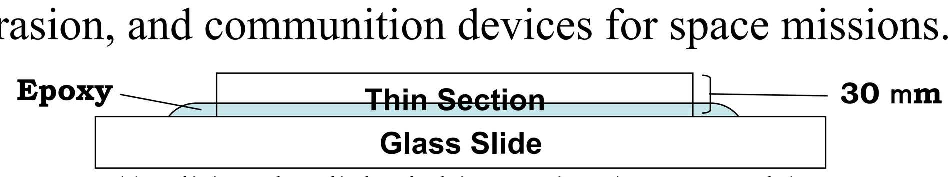
We present a conceptual design of the ***In Situ*** **A**utomated **R**ock **T**hin **S**ection Instrument (IS-ARTS). We have studied the limiting steps toward the development of the instrument, which enables us to present estimates of power, mass, lifetime, and number of thin sections produced by a given system. We have developed methods for rough cutting, epoxy/slide application and grinding/polishing to finished thin section quality. An automated thin section device and petrographic microscope will enable "sample-return science" from a non-sample-return mission.

Scientific Context

Thin section analysis provides a perspective to understanding planetary surfaces that will be uniquely different from the viewpoint obtainable from any previous orbital or surface missions. A thin section instrument will provide the first definitive data for understanding the surface of planetary bodies. For example, 1) understanding the diversity across interfaces between weathered and unweathered lithologies would provide insights into the history of the planets surface processes, 2) providing valuable information on the composition, and potential environments of formation of surface minerals, and 3) help establish the chronological history of the surface by providing a mineral context for *in situ* age dating of materials.

Technical Context

Thin sections are used to identify minerals, their structural aspects (cleavage, fractures, mineral zoning) and rock textures that indicate the mode of formation of the rock. A thin section is a sample polished on two sides and ground to ~30 mm thickness; the thin section is typically glued to a microscope slide. Translation of the thin section to the spacecraft environment requires careful consideration of consumables, sample manipulation and the lifetime of cutter/grinder/polisher surfaces. The technical problem is most similar to the development of drilling, coring, abrasion, and communition devices for space missions.

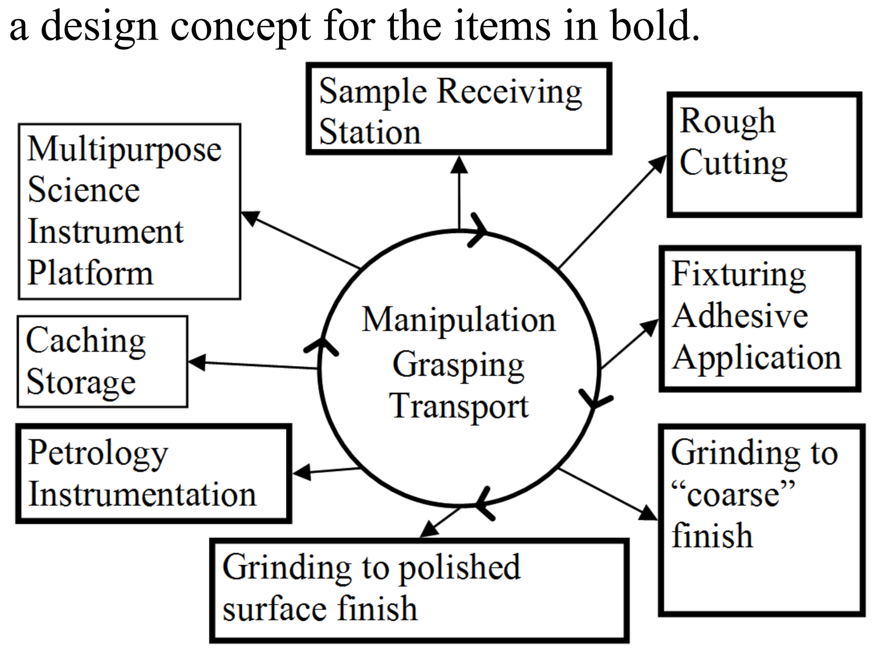


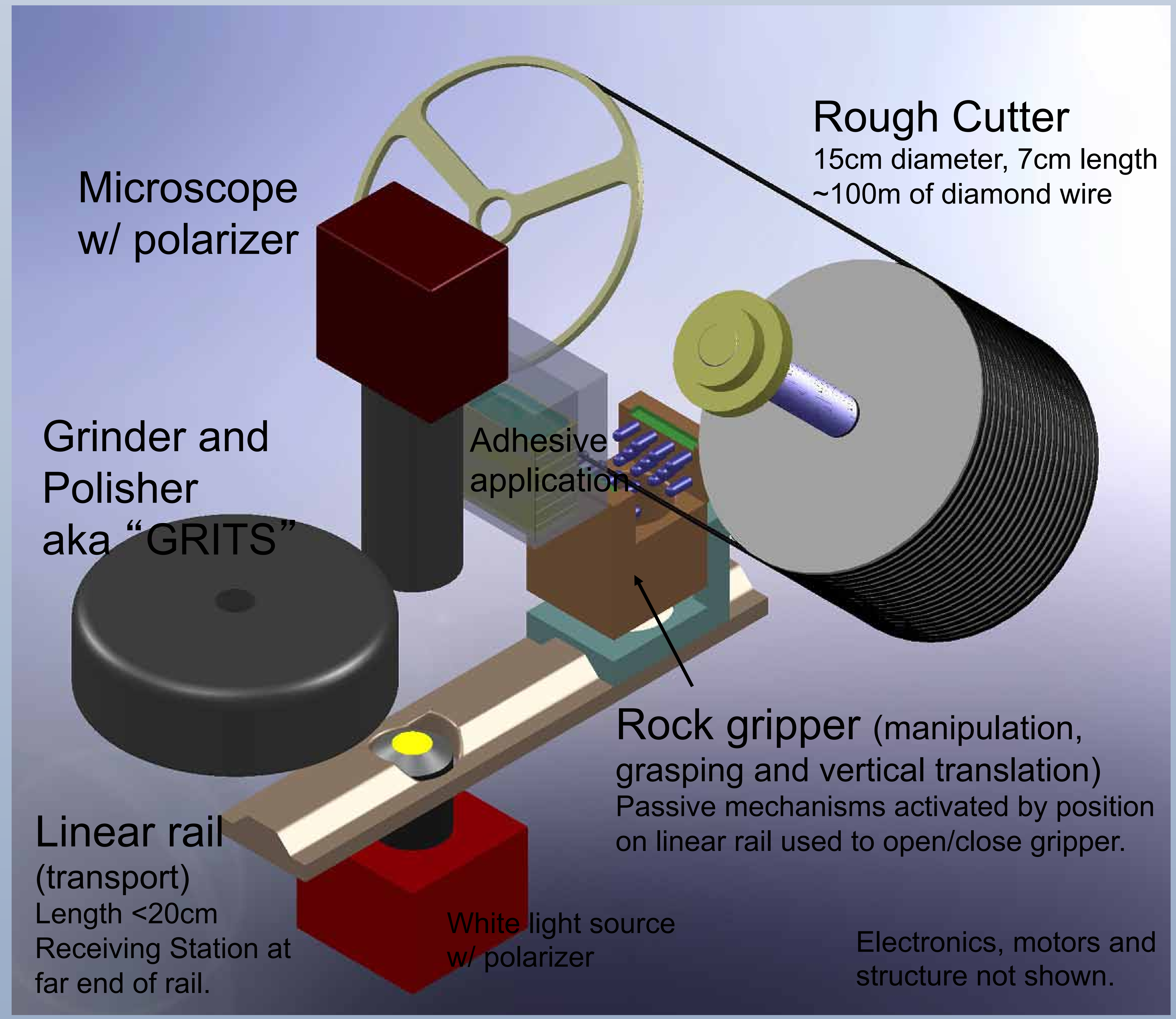
Traditional polished thin section (not to scale)

Instrument Work Flow

Thin section preparation is traditionally a manually intensive task. The schematic below orders major tasks in a spacecraft context. Work proceeds clockwise starting at the top with iteration possible between steps. We are presenting a design concept for the items in bold.

We envision the production of a thin section to be performed as a series of autonomous steps with periodic verification by a science and engineering team in mission operations.





Mass, Power and Performance Estimates

Sample processing capabilities 50 thin sections of basaltic rock. Processing time of 1 thin section over several days. System requirements: 100m wire, 5mm thick GRITS abrasive, initial rock fits within ~20mm cube.

Item	Basis (TRL)	Mass (kg)	Item Power (W)	Power (W) during a sustained operation: Cutting	Grind/polish	Imaging	Manipulation	Epoxy Set	Verification
GRITS	HBR (TRL4)	4.5	10-20		20				
Microscope + Transmitted Light	MAHLI (TRL9)	0.7+ 0.5	5+1			5+1			
Epoxy/Slide	JPL (TRL3)	0.5	1					1	
DWC	CSM (TRL4)	2.5	7	7					
Linear Rail	Estimate	1.0	3	3	3		3	3	
Gripper and Vertical Translation	Estimate	0.5	3				3	3	
Engineering Camera	Estimate	0.2	2						2
Structural system, housing etc.	Estimate	3	0						
Control Electronics	Estimate	1	<1						
	Total	**14.4**		**10**	**23**	6	6	7	2

Forthcoming Publications:
1. Dreyer, C. B, K. Zacny, J. P. H. Steele, J. R. Schwendeman, G. K. Paulsen, R. C. Andersen, J. Skok, (2012) Development of a Thin Section Device for Space Exploration: Overview and System Performance Estimates, ASR (in press).
2. Paulsen, G., K. Zacny, C. B. Dreyer, M. Szczesiak, J. Skok, C. Santoro, A. Ashley, (2012), Robotic Instrument for Grinding Rocks Into Thin Sections (GRITS), ASR (in press).
3. Dreyer, C. B., J. Schwendeman, J. P. H. Steele, A. Niedringhaus, J. Skok, (2012) Development of a Thin Section Device for Space Exploration: Rock Cutting Mechanism, ASR (in press).

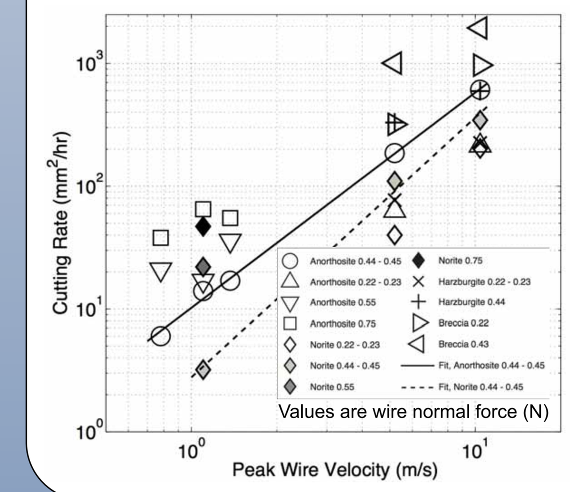
Conceptual Design

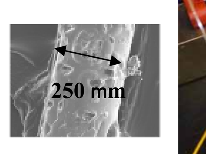
Solid model of the conceptual design shown in center. Performance estimates are given in the table lower center and are based on work in TRL3/4 test beds.

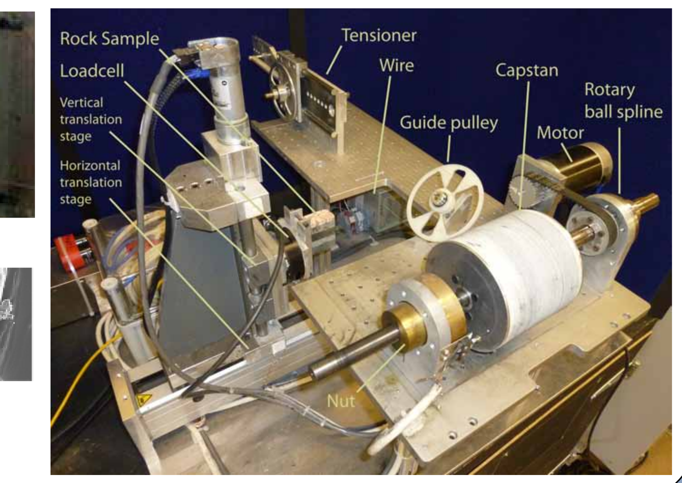
Test Beds: TRL3/4 validation

Rough Cutting Test Bed

The diamond wire saw requires **less energy**, **reduces over-cutting waste** (kerf), produces **less dust**, it can cut in **multiple directions**, and **reduces** system **mass** and **volume** relative to other cutting devices. A capstan design allows up to 200m of wire in rel. small vol. (1500 cm^3).
→ Cutting Rate, Wire Lifetime, Specific Energy and rock configuration have been tested on a variety of samples in 4 test beds.





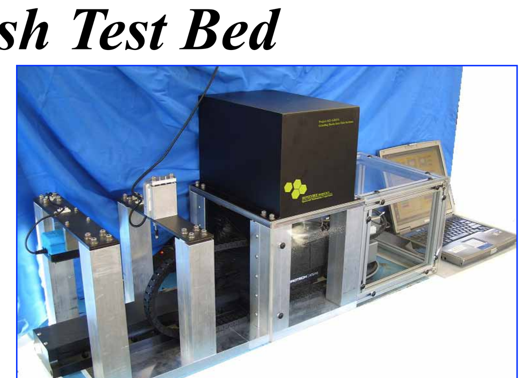


Adhesive Application

The application of glue to bind a sample to a microscope glass slide. Investigated approaches: UV cure, thermoset, combined slide and epoxy, and slide-free approaches. Requirements include compatibility with the space environment, opaque, high refractive index, does not alter the sample, and does not obscure significant chemical signatures.

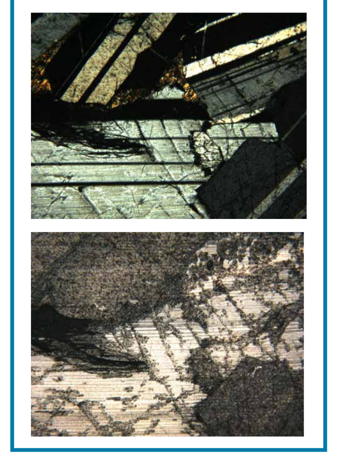
GRITS: Grinding/Polish Test Bed

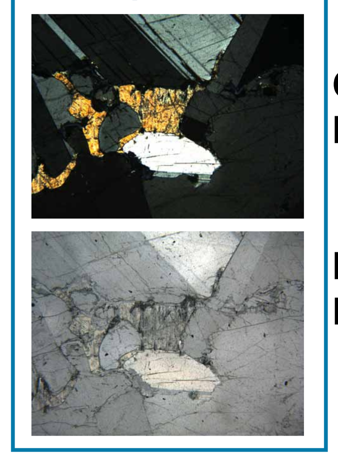
Grinding **R**ocks **I**nto **T**hin **S**ections is a combined **dry** grinder and polisher. By careful control of force 4mm of rock can be removed and the surface finished with an adequate thin section polish. The test bed has been used to test several different grinding/polishing wheels and explore load, speed and oscillation parameters. We have successfully shown the ability to produce thin sections.



Microscope images show **success** of GRITS dry grinding/ polishing. The section can be used for petrographic analysis and was prepared in a method compatible with spaceflight

Anorthosite



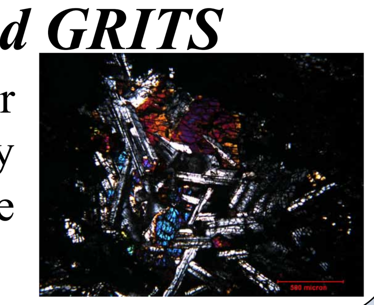


Crossed Polarizers

Reflected Light

Integrated Test of Rough Cut and GRITS

We have tested the Rough Cutter and GRITS together by a manual had off of a cut sample, manual epoxy application, and GRIT grind/polishing. Results are promising. Results with Saddleback Basalt →



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