THE CAESAR NEW FRONTIERS MISSION: 3. TAG SITE SELECTION AND CAMERA SUITE.

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Introduction: The Comet Astrobiology Exploration Sample Return (CAESAR) mission [1] will acquire and return to Earth for laboratory analysis > 80 g of surface material from the nucleus of comet 67P/Churyumov-Gerasimenko (67P). A key to mission success is to select a Touch-and-Go (TAG) site that provides high science value, and that is fully compatible with safe and successful sampling. In order to select and document the TAG site on 67P, CAESAR carries a suite of six cameras of varying fields of view and focal ranges.

If sampling a poorly explored or unexplored comet, a substantial payload of instruments would be needed to study the nucleus thoroughly enough to allow wise sample selection. By going to the comet that has already be studied in detail by Rosetta, this need is reduced. A cornerstone of the CAESAR mission is to carry only the instruments necessary to successfully acquire, document, and provide context for the sample. This guiding principle allows our precious and limited resources to be focused on maximizing the scientific value of the returned sample [2], while minimizing cost and risk.

TAG Site Selection: Following the OSIRIS-REx mission architecture, CAESAR will select TAG site candidates by developing four maps of 67P: the Safety Map (SFM), the Sampleability Map (SPM), the Deliverability Map (DM), and the Science Value Map (SVM). Any candidate TAG site must have acceptable properties on all four maps. Figure 1 shows preliminary versions of the maps, generated using Rosetta data. The CAESAR-produced maps will be evaluated by a TAG Site Selection Board chaired by the DPI. The TAG site will be selected by the PI based on their recommendation, with concurrence from the NASA AA for SMD.

The SFM shows regions whose properties permit a safe TAG event, and incorporates factors such as the radial vector-relative surface tilt and Earth communications. The SPM identifies regions that are compatible with the demonstrated capabilities of the Sample Acquisition System (SAS) [3]. Mirroring selection of Mars landing sites [4], we analyzed the size-frequency distribution of boulders on 67P using the highest resolution Rosetta (14 cm/pixel) and Philae (0.95 cm/pixel) images [5]. We also measured the small-scale roughness and cm-scale slopes using a photoclinometry method that has enabled spacecraft to land safely on Mars [6]. The DM depicts regions where the spacecraft can navigate to the surface for TAG and meet all deliverability requirements, mainly position accuracy and velocity constraints. The SVM uses remote sensing data and detailed dynamical and thermodynamical calculations to identify regions on 67P best suited to addressing CAESAR's science questions. Organic matter and ices are ubiquitous, so there are no areas of low science value. Because the concentration of organics is high and nearly constant across 67P's surface, variations in the distribution and activity of volatiles as determined from Rosetta color imaging [7] and surface morphological changes, both of which indicate volatile-rich areas, are dominant components of the SVM. Two CAESAR cameras include color filters that are identical to the subset of the Rosetta filters used to map volatiles on 67P. Possible TAG sites are numerous and widely distributed.

Geophysical and Geomorphic Context: The CAESAR Camera Suite will determine the geologic and geomorphic context of the CAESAR TAG site. Material that does not escape during sublimation events collects as airfall deposits in sedimentary basins to form the smooth terrain [9,11,12]. While these areas are relatively featureless at m-scale, Philae images show significant texture at cm-scale that can inform process [13].

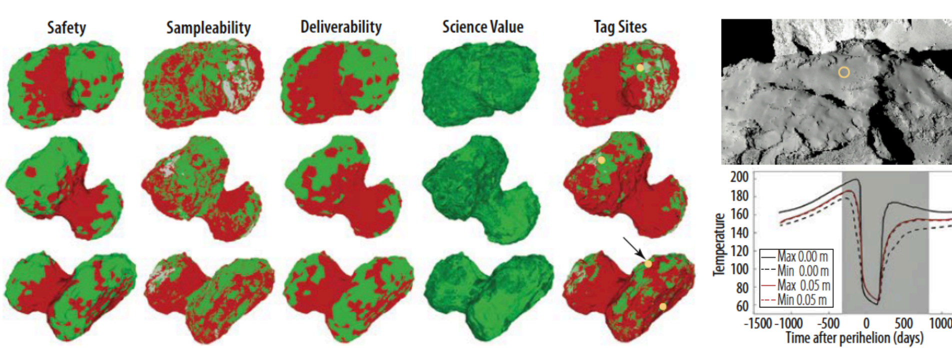


Figure 1: Four TAG site selection maps are merged to produce a final TAG Site Map. Four preliminary sites are indicated in yellow. Upper right shows one site, in the Ash region of 67P, with its 3-σ error ellipse (29 m. Lower right gives calculated [8] temperatures for that site; days not shaded are accessible for TAG.

Migration of material to the smooth terrains has been attributed to the obliquity and eccentricity of 67P's orbit [9]. Higher insolation in the southern hemisphere around perihelion increases sublimation rates, providing energy necessary to launch water-ice rich particles, which settle in the cold gravitational lows of the northern hemisphere [9]. This material has also been shown to frequently reorganize at m-scales, and was the dominant type of terrain modification observed by Rosetta [14–15]. This reorganization indicates water ice is present in the very near subsurface [16]. Additional m-scale changes should be expected when CAESAR arrives.

To discern the relative importance of these processes and determine sample provenance, CAESAR will acquire mm-scale images of the TAG site, cm-scale images of the TAG ellipse, and decimeter scale images of the entire comet. The mm to m-scale morphology and topography revealed by the Camera Suite will permit detailed reconstruction of the sediment transport system responsible for depositing the collected sample.

CAESAR Camera Suite: The CAESAR Camera Suite (Figure 2) is a suite of six cameras developed by Malin Space Science Systems (MSSS) and built around common camera head electronics based on the MSSS ECAM Imaging System. The camera suite consists of a narrow angle camera (NAC), medium angle camera (MAC), touch-and-go camera (TAGCAM), two navigation cameras (NAVCAMs), and a sample container camera (CANCAM). The suite has inherent functional redundancy and operational flexibility. Each camera is based on a system currently operating in flight, with engineering developments that tailor each element to meet specific CAESAR requirements. All elements of the Camera Suite are currently TRL 6 or above.

The NAC is derived from the twin Lunar Reconnaissance Orbiter (LRO) NACs, which have been operating for > 9 years and have returned over one million images. The driving requirement for the NAC is to resolve 4.5-cm particles during High Altitude Recon (800 m range). It will accomplish this by acquiring diffraction-limited 0.8 cm/pixel images at SNR > 100.

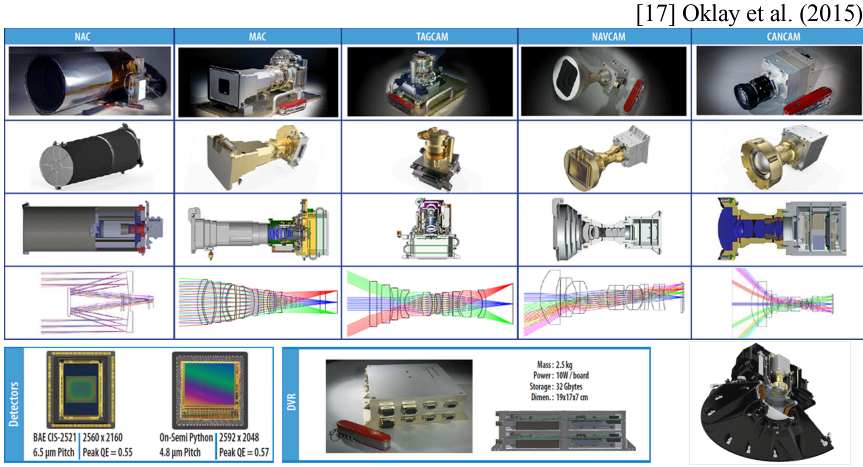
The MAC is derived from the MSL Mastcam 100, which has been operating on Mars for > 6 years. The driving requirement is a 5° FOV to support optical navigation, and it can support TAG site selection in the event of NAC failure by acquiring 0.4 cm/pixel images at SNR > 100 from Matchpoint (50 m range). Both the NAC and MAC have 8-position wheels that carry filters whose bandpasses are identical to the Rosetta OSIRIS NAC NUV, blue, orange, red, NIR, and IR filters [17].

The driving requirement for TAGCAM is to document the TAG site before, during, and after TAG. TAGCAM will acquire 1 mm/pixel diffraction-limited images at SNR > 100 during TAG from a range of ~3.5 m. TAGCAM is derived from the MSL Mars Hand Lens Imager (MAHLI), which has been operating on Mars for > 6 years and has returned >50,000 images.

The two NAVCAMs employ a 30°×40° FOV to support TAG optical navigation and are derived from the OSIRIS-REx NAVCAMs, which have been performing as designed in flight for > 2 years.

CANCAM will document sample acquisition during TAG and is packaged inside the SAS at the end of the arm. CANCAM views the interior of the sample container through a powered sapphire window using its own LED array. After sample container stowage, CANCAM can be used to inspect the sample container as well as other parts of the spacecraft.

References: [1] Squyres et al. (2017) *LPSC* [2] Lauretta et al. (2017) *LPSC* [3] Glavin et al. (2017) *LPSC* [4] Golombek et al. (1997) *JGR-P 102,* [5] Birch et al. (2017) *MNRAS 469* [6] Kirk et al. (2003) *JGR-P 108* [7] Fornasier et al. (2015) *A&A 583* [8] Davidson and Rickman (2014) *Icarus 243* [9] Thomas et al. (2015) *Science 347* [10] Sierks et al. (2015) *Science 347* [11] Keller et al. (2015) *A&A 583* [12] Groussin et al. (2015) *A&A 583* [13] Mottola et al. (2015) *Science 349* [14] Hu et al. (2017) *A&A 604* [15] El-Maarry et . (2017) *Science 355* [16] Fornasier et al. (2016) *Science 354* [17] Oklay et al. (2015) *A&A 583*



Camera Technical Details

	NAC	MAC	TAGCAM	NAVCAM	CANCAM
IFOV (µrad)	9.3	70	296	272	533
FOV-x (°)	1.36	7.40	26.9	40.7	75.7
FOV-y (°)	1.15	5.60	26.9	32.7	60.6
AoΩ ($\mu m^2 sr^1$)	2.56	2.10	2.10	1.50	1.48
Focus (m)	100-inf	50-inf	1.0-inf	9.3-inf	0.1-inf
Total Mass (kg)	10.2	1.25	0.83	1.0 (x2)	0.705
Elec. Mass (g)	475	475	475	402	402
Optics Mass (g)	9700	775	350	596	303
Peak Power (W)	5.0	5.0	5.0	3.5	5.0
Stdby Power (W)	3.5	3.5	3.5	2.5	2.5
Length (cm)	98	27	11	7.0	7.0
Width (cm)	27	11	11	7.0	7.0
Height (cm)	27	11	11	20	15
Cover	Opaq	Opaq	Trans	Trans	None

Figure 2: CAESAR Camera Suite CAD Models, Ray Traces and, Technical Details