ADVANCED POINTING IMAGING CAMERA (APIC) CONCEPT. R.S. Park[1] and J.E. Riedel, [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA (e-mail Ryan.S.Park@jpl.nasa.gov)

Introduction: The Advanced Pointing Imaging Camera (APIC) is a high-resolution imaging system which simultaneously takes images of targets and star fields with two-axis pointing control capability, allowing rapid target imaging and image motion compensation (IMC) with extremely precise pointing knowledge. Such imaging data can accurately measure the geophysical property and high-resolution topography of target objects. Figure 1 shows the CAD drawing of APIC and Table 1 shows its characteristics.

Main Objectives: The main science application of APIC is to serve as a geodesy/geophysical instrument which can provide the data to constrain the interior structure of planetary objects. Specific science objectives include: determination of geometric tidal flexing of natural satellites and determination of rotational libration, nutation, and precession of natural satellites and asteroids.

Science and Engineering Enabled by APIC:

- APIC's 2-DOF actuation would allow significantly more effective and efficient science/mission operations by providing rapid and flexible imaging capability (*e.g.*, much less constraints on spacecraft operational geometry).

- APIC's IMC ability, using the internal gimbal and attitude knowledge dramatically reduces the implementation and operational cost of IMC for any mission, and increases the achievable resolution of fast flyby missions.

- APIC's high-resolution narrow-angle-camera (NAC) and wide-angle-camera (WAC) would provide important unique science return via the ability to simultaneously take the images of the target body and star field, allowing high-resolution surface imaging with extremely precise pointing knowledge. Such imaging data with precise pointing information can accurately measure the tidal deformation and/or libration/precession of the target body, and thereby reveal target body's interior structure

- Furthermore, APIC can provide data for stereo (or stereophotoclinometric) reconstruction of target topography, including shape, size and volume, with control networks that would provide very accurate determination of the target-relative position of the spacecraft.

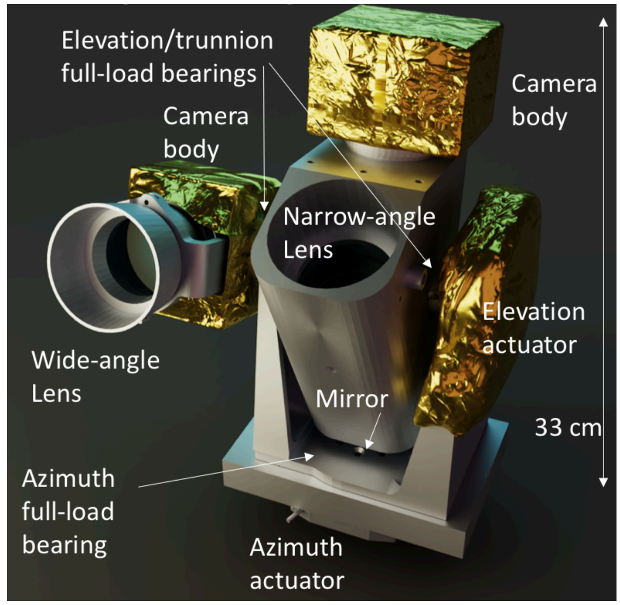

Figure 1: Mock-up of APIC with component insulation.

Parameter	Values
Dimension	~2U
Mass	<5 kg
Power	12 W
Image Resolution	19 µrad
Pointing Knowledge	2 arcsec
Az Range	inf
El Range	±90°
Az max rate	0.5 /s
El max rate	0.5 /s

Table 1: APIC characteristics.

- APIC's combined functionalities would offer a powerful optical navigation capability, that would significantly enhance spacecraft orbit reconstruction and prediction accuracy, and thus, potentially reducing operations costs. Furthermore, APIC can serve as an ideal platform for autonomous navigation and internal star-finding/tracking can provide backup attitude information for the host spacecraft

APIC functionality: The core of the APIC structure is the two degree of freedom gimbal. This gimbal is comprised of an Azimuth axis, which rotates about a base attached to the spacecraft body, and turns a yoke or "U-bracket" which carries the telescope and star camera on a trunnion axle for Elevation motion. One of the motor-actuators is housed within the base, and turns the yoke. Another motor-actuator is mounted on the trunnion axle and turns the telescope and star camera in Elevation. Incorporated into the base and the U-bracket are the bearings necessary to carry the mass of the mechanical and optical elements, especially under launch conditions.

Two very compact precision rotary stages are used in the APIC design. These are flight-adapted versions of otherwise COTS vacuum and low-temperature tolerant laboratory devices. The motors utilize ceramic piezo drives, capable of very precise motion, with a rotary precision of four microradians by virtue of high-precision optical encoders incorporated into the stage.

The two sets of optics, narrow and wide, are custom designed for APIC, and are both refractive optical sets, with the NAC being a folded optical design. The NAC is a 350 mm Focal Length, 60 mm aperture (F 5.8) refractive (and folded) optic. The WAC is a 70 mm, 60 mm aperture (F 1.2) lens. The radiation hardened optics are also specifically designed to be tolerant of thermal gradients. The temperature of the optics will be controlled by heaters, and isn't expected to vary by more than two degrees C, but thermal stability is critical for precision determination of the pointing angle of the telescope by the star camera, and only an arcsec of variation can be budgeted for thermal affects.

APIC has a central processing unit, which will command the cameras and actuators and interface with the spacecraft via a high-level command interface. The motor/actuator builder is also providing a two-channel (one for each gimbal axis) flight-ready controller board for the actuators, which will be commanded with directives in the APIC Az/El frame. However, the spacecraft will command APIC with directives in Celestial RA/Dec, with the conversion to Az/El being performed in the APIC processor, using the current spacecraft attitude. The APIC software will plan the attitude and turn rates of the instrument to meet the commanded need of pointing and rate. It should be noted that absolute pointing accuracy of the instrument is not critical; it is knowledge that is critical – which comes from the Star Camera. The absolute pointing accuracy might be limited by the accuracy of the spacecraft star tracker, which in all cases meet the modest absolute pointing needs of the instrument. APIC will also be dependent on the accuracy of the slew rate of spacecraft, the motion of which will overlay on the action of the gimbals. Spacecraft gyros are typically very accurate, and – especially when equipped with momentum wheels – typical spacecraft can meet the tight platform control stability requirements of APIC.

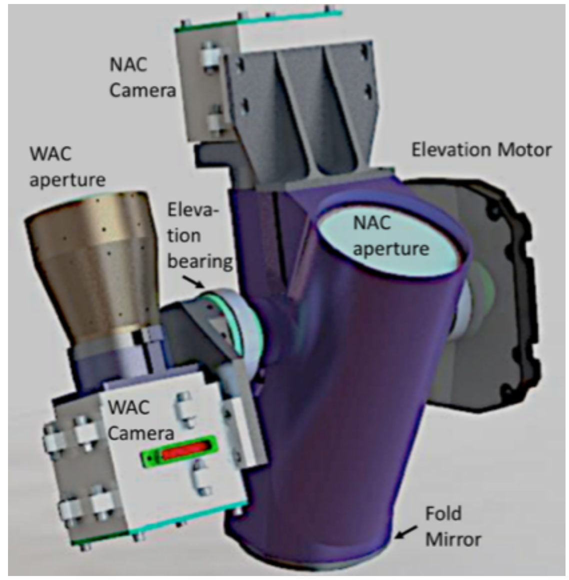

Figure 2: Final flight configuration of the APIC's NAC and WAC (oriented at 45° from the NAC boresight).

APIC Current Status: The APIC development is in its third year of JPL IRAD development, and will produce a TRL 6 flight-like prototype that is intended to be capable of up-grade to a Class D flight, such as for NASA's SIMPLEx mission. Substantial applicability of the in-hand components (such as optics) could also be applied to a Class B flight, such as Discovery or New Frontiers, for substantial cost savings for those potential mission hosts relative to a new-build instrument. At the time of writing, the flight optics are about to be received, and the team is preparing to contract with PI for the building of the flight actuators and controllers. The final designs are in hand for the telescope body (Figure 2), and fabrication is commencing. Some design optimization – principally lightening – will be done on the base and U-bracket. These elements may be 3-D additive printed in aluminum. The Telescope body will be conventionally machined, with procedures and processes developed in the fabrication of the functional prototype. This prototype will be used in the field (from JPL's Table Mountain Observatory) to demonstrate functionality of the instrument using non-flight optics and actuators.

Acknowledgement: This work was carried out in part at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.