A "PARC" SYSTEM FOR TERMINAL DOCKING

by

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A Panoramic viewing system for Automated Rendezvous and Capture (PARC) has been proposed as a visual information feedback system for terminal docking/berthing. The system relies on a unique Panoramic Annular Lens (PAL) which captures an image of its surroundings in real time.

This paper describes the evolution of the PAL along with technical details of its imaging capabilities. Several examples are given of radial metrology, where PAL imaging systems are used to perform visual inspections and measurements. Digital image acquisition and processing techniques, used to interpret various features appearing in the images and to transform images for improved human viewing, are also included. These discussions are followed by a potential application for PARC involving berthing of active and passive mechanical assemblies associated with Space Station Freedom.

The first attempt to design a system for panoramic imaging was made by Mangin in 1878.[1] Since that time, numerous devices have been patented.[2] These endeavors can be divided into two main groups: those in which the imaging device or a part of it is rotated around its axis to scan the area of interest, and those which utilize combinations of optical elements to obtain a single panoramic view. These optical elements may have several refracting/reflecting parts with collinear optical axes or may consist of a single block having several refracting and reflecting surfaces. Unfortunately, these compound systems are often difficult to manufacture and miniaturize if high quality panoramic images are needed. Scanning techniques[3,4] also have disadvantages; beside the need for a rotating mechanism, no simultaneous viewing of the entire space is possible. These constraints severely limit functional and real-time capabilities. Fortunately, many of the drawbacks of both compound and scanning systems were eliminated in the development of the panoramic annular lens (PAL).[5]

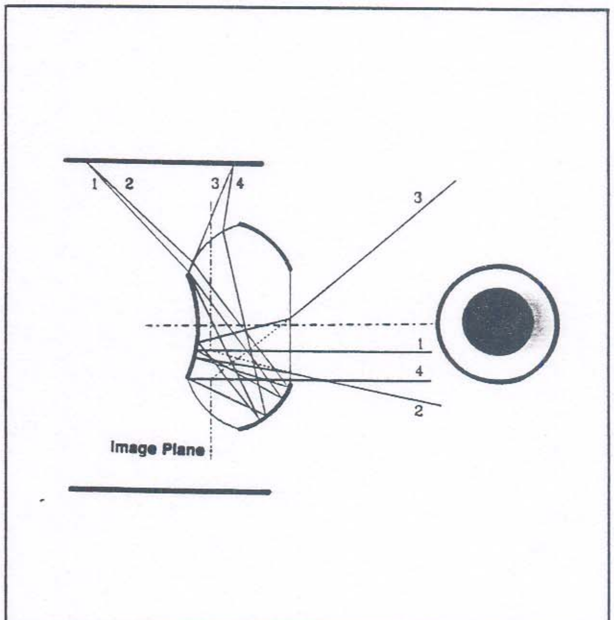

Figure 1. A ray diagram of the PAL.

The PAL is a single element lens, with spherical surfaces, which collects light for imaging and then forms an internal virtual image of its surroundings. Figure 1 shows some rays traced through the PAL, and the location of the virtual image. Since the annular image is formed within the PAL itself, it must be transferred to an image capturing device using a collector lens. Figure 2 shows that the field of view for a typical PAL extends from 20° below the horizon to 25° above the horizon, 360° around. Figure 3 shows an image taken with the PAL to demonstrate its unique characteristics.

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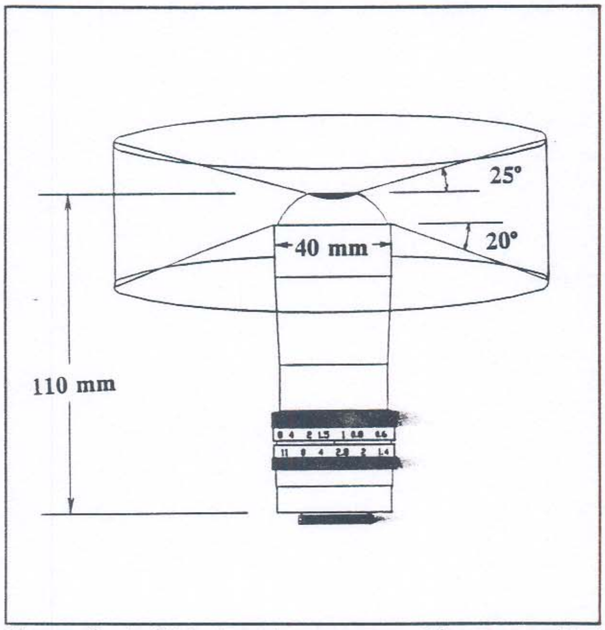

Figure 2. A PAL imaging system. Figure provided courtesy of Optechnology, Inc.

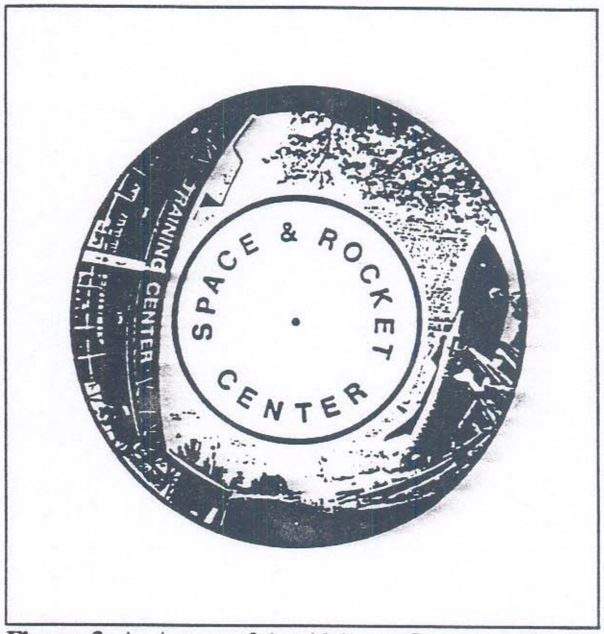

Figure 3. An image of the Alabama Space and Rocket Center taken with a PAL camera.

Various tests and experiments have been performed to illustrate that the PAL can be used as a profilometer,[6,7] for panoramic imaging and visual inspection;[8-10] and, in conjunction with speckle,[11,12] moire,[13] and holographic[14,15] measurement techniques. Computer algorithms for linearizing the annular images have also been developed.[10]

These studies form the basis for a PARC system which is being considered for applications involving terminal berthing/docking associated with Space Station Freedom, and other space-based operations connected with the Space Exploration Initiative.

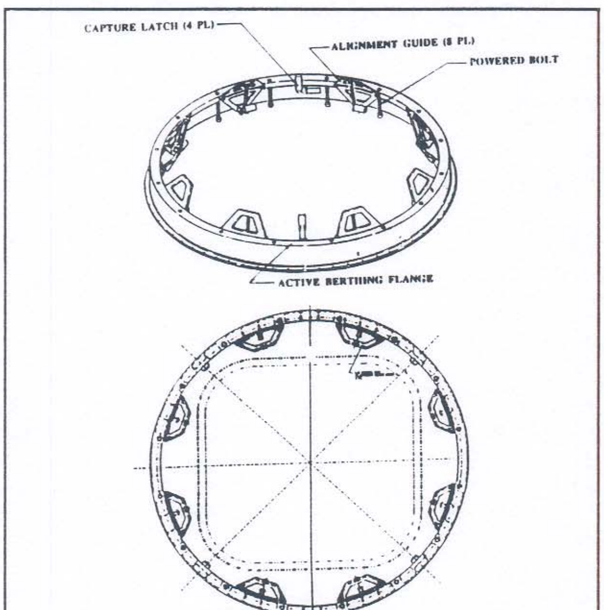

Figure 4. Active berthing assembly showing alignment guides (petals), latches, and berthing flanges.

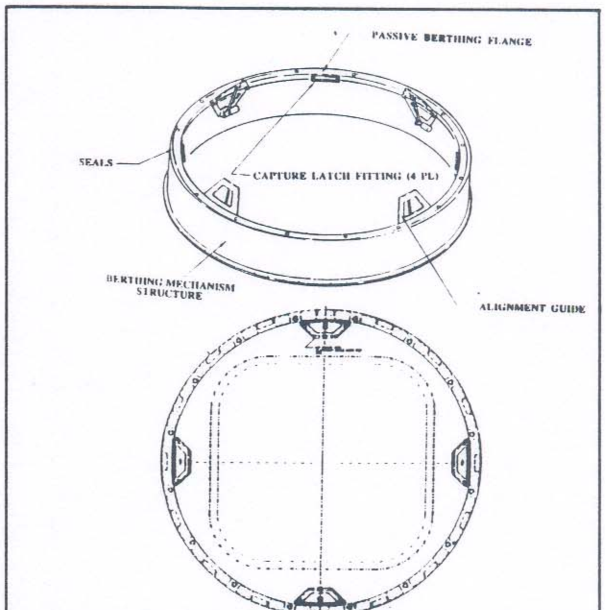

Figure 5. Passive berthing assembly showing alignment guides (petals), latches, and berthing flanges.

Figures 4 and 5, for example, show the current designs proposed for active and passive berthing mechanisms on space station. The petals on the assemblies are used as alignment guides; a critical need exists to sense the relative positions of the petals with respect to the flanges in order to facilitate berthing and to ensure that the modules are sealed properly. A multi-camera system can be used to monitor this operation; however, placement of the hardware and synchronization of the images pose significant problems.

An alternate approach has been proposed to the Marshall Space Flight Center in which a PARC imaging system is mounted on the hatch of an active module. Plans call for mounting the PAL adjacent to the viewing window and capturing images using a CCD camera. Near term feasibility tests include a 6-degree of freedom simulation with hardware in the loop.

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