Indian National Society for Aerospace and Related Mechanisms
BANGALORE CHAPTER

E-NEWSLETTER

Vol. 3, No. 2, May 2009

From the Editor

Dear Member,

Considerable interest has re-emerged on the moon. A series of spacecraft missions to study the moon by different space faring nations is a grand testimony to that. The keen interest to explore the moon's surface from a commercial standpoint with lunar rovers has acquired fresh impetus. In this direction, an ISRO-STC project on the mobility system of a lunar vehicle using the biomimetic software IDEA-INSPIRE was completed and presented to Spacecraft Mechanisms Group engineers by the joint ISAC–IISc team.

This issue has an article on the development and testing of a large radar antenna hold down, release and deployment mechanism. It describes a new concept of a latching device and reports satisfactory performance of a full scale model. Further, in recent times, considerable research and development has taken place in the area of low shock release systems for deploying appendages in spacecraft on-orbit. This issue carries a study article on this topic dealing with contemporary low shock release devices.

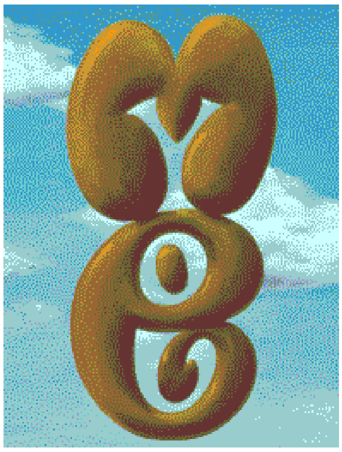
This newsletter is intended to be a medium of information exchange regarding the state of the art developments and future directions in the area of mechanisms and related fields. The editorial committee looks forward for your active participation in the form of technical articles and ideas which will certainly enhance the technical value of this e-newsletter.

With best regards,

Dr. R Ranganath, FIE
Chief Editor

CONTENTS

FROM INSARM BANGALORE CHAPTER



For Latest Updates & Membership form please visit

www.insarm-bangalore.org

www.insarm-bangalore.org/INSARM__membership_form.pdf

LARGE RADAR ANTENNA DEPLOYMENT MECHANISM FOR SPACECRAFT

M.V. Ramakrishna & M.K Ravindran
Spacecraft Mechanisms Group, ISAC, Bangalore-560017
E-mail: mvramak@isac.gov.in

INTRODUCTION

One of the remote sensing satellite carries a large radar antenna. A typical configuration of the radar antenna payload at launch and in orbital configurations are shown in Figures-1a & b. The SAR antenna is *6.240 m x 2.383 m size* and it is made up of three panels. The middle panel-1 is rigidly fastened with the spacecraft body and the two deployable panels, panel-2 and panel-3, are hinged on either sides of the middle panel-1. Each panel measures *2.073 m x 2.383 m x 197 mm* and weighs *285 Kg.* The depth dimension of 197 mm of panel gives stiffness to antenna in deployed configuration. These panels are folded and held over the triangular spacecraft body during launch and deployed in the orbit. The large size and heavy antenna panels needs special consideration for stowage, deployment torque margin, a low deployment latch up shock load and least deployment repeatability errors. These requirements necessitated the development of a novel mechanism which is addressed in this article.

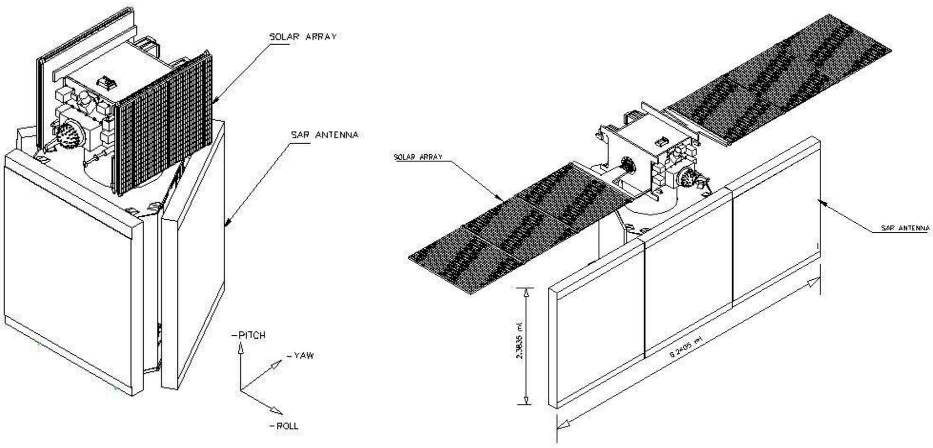


Figure 1a & b: Spacecraft with SAR antenna stowed &deployed

SPECIFICATIONS:

Deployed Antenna dimensions	6.240 m x 2.383 m x 197 mm thick
No. of antenna panels	3 (middle panel 1 ; dep. panels 2)
Size of each panel	2.073 m x 2.383 m x 197 mm thick
Mass of each deployable panel	285 kg
Deployed antenna flatness	< 2 mm
Deployable antenna panel repeatability errors	0.007^0 (0.24 mm over 2 m length)
No. of hold down points	4 per panel
Deployment angle	120^0
Electrical cables to be routed from dep. panel to spacecraft body	172
Launch load at each Hold down point	2,000 Kgf – inplane / Out of plane
Deployed natural frequency of antenna	≈ 1 Hz
Orbital temperature	-50^o C to + 70^o C

MECHANISM DESCRIPTION

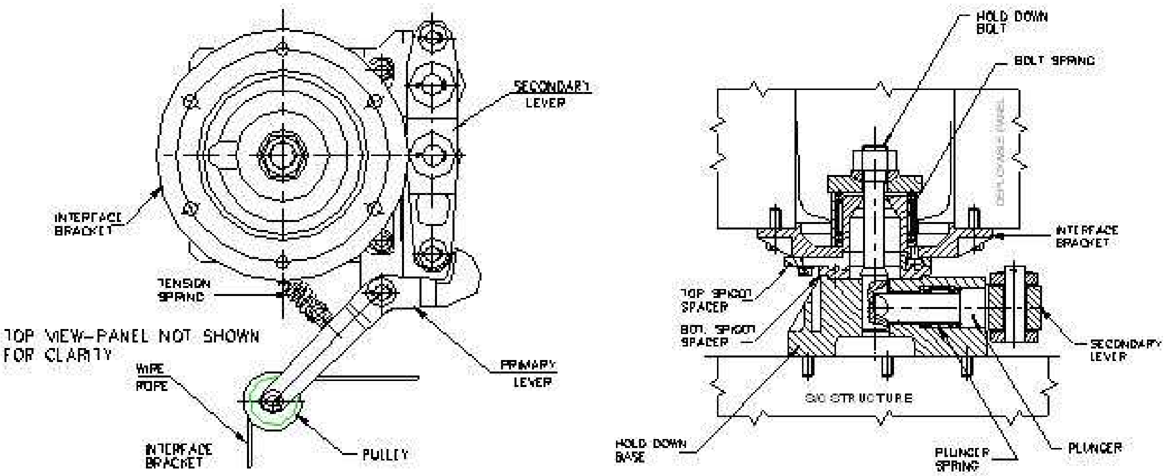


Figure 2: Hold down assembly in held down mode

The deployable antenna panel has four hold down assemblies and a release mechanism. Schematic of hold down assembly is shown in Figure-2. This mechanism is derived from the previous spacecrafts and modified to meet higher strength and stiffness requirement. All the hold down bases are mounted on spacecraft body and are interconnected by means of a release mechanism. The tension in release mechanism loop keep all the bolts in position. In launch mode, the preload in bolt provides the clamping force on panel and transfers the launch load acting on panel to the spacecraft body. On cutting the release loop by a pyro-cutter, the tension in rope loop is released. This results in the simultaneous release of all the hold down bolts and the antenna panel is allowed free for deployment.

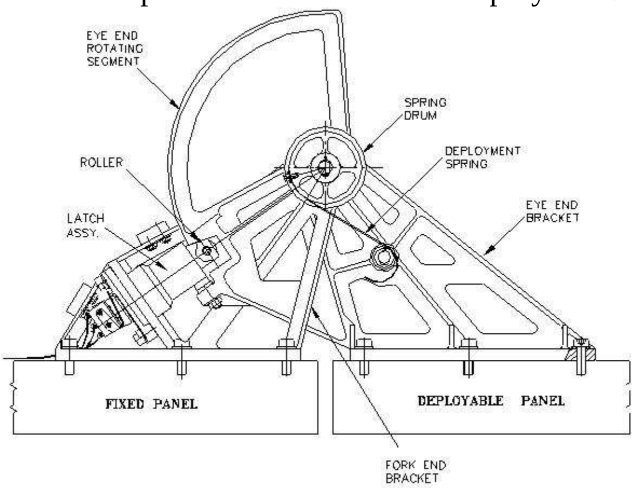


Figure 3: Hinge in deployed mode

A pair of hinge assemblies are used to connect middle panel-1 with deployable panels-2/3, at top and bottom. The deployed configuration of hinge assembly is as shown in Figure-3. The hinges have spherical mono-ball bearings to take care of small misalignments. Constant torque springs in hinge assembly deploy the panel. Dampers are used to control the deployment rate and a latch mechanism will latch up panel at the end of deployment. Dampers will ensure latch up shock moment to be with in acceptable limit. Eddy current damper used in earlier spacecrafts, is modified to meet the required higher damping rate. Minimum backlash in hinge bearing and latch assembly is achieved by close control of dimensions and tolerances. Also, an adjustment screw and spacer are used in latch assembly to implement the fine tilt angle corrections to achieve the required flatness.

The magnitude of drive torque for deployment is very high due to the large inertia of panel, friction in hinge and the resistance offered by electrical cables. Four laminations of constant torque springs are used per hinge assembly. The lamination is flat SS 301 material of 0.3 mm thick, 25.4 mm width and 165 mm length. This is cold formed to coil form with an inner diameter of 44 mm and then stress relieved. Later, spring is passivated and dry lubricated. About 172 signal and power cables are routed from deployable panel to spacecraft body. The loops are configured such that they offer minimum resistance during deployment.

DEVELOPMENT MODEL & TEST: A full size development model, using simulated spacecraft structure and dummy antenna panel is fabricated, assembled and tested. Figures-4a and 4b presents the antenna development model in stowed and deployed configurations. The model used flight quality mechanisms and the electrical cable loops in flight configuration. From the deployment tests conducted under zero-g condition by using air levitation system, all the mechanism functional requirements / specifications are checked and verified.

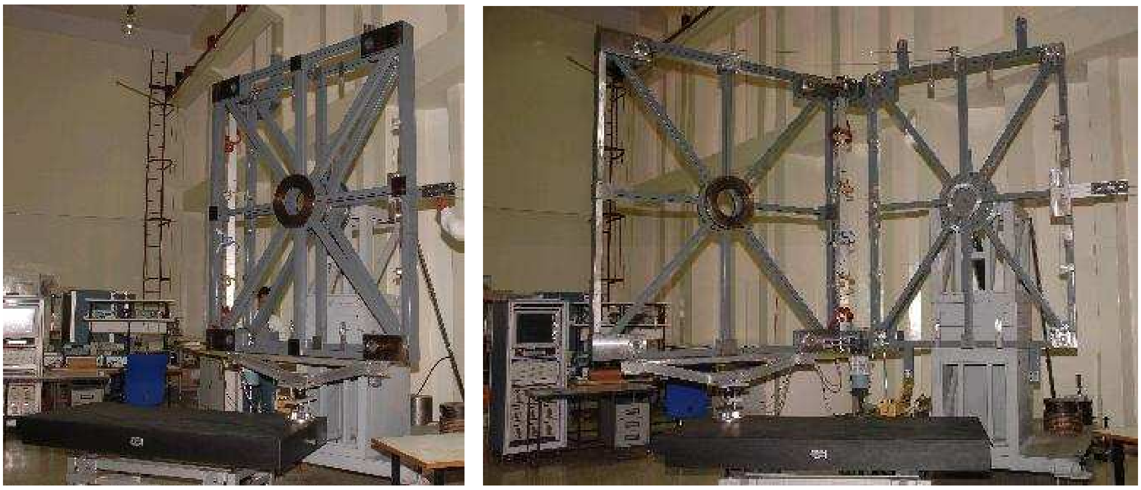


Figure 4 a & b: Antenna development model in Stowed & Deployed configuration

CONCLUSION

This mechanism is a new development and proven concepts of earlier developments have been used and modified to meet functional requirements. High torque constant torque/ negator springs and a new concept of latching device are designed and used. Dampers are modified to give high damping rate. Design provision is made for antenna tilt angle corrections and adjust the antenna planarity of *2 mm*. Mechanism performance is checked and verified by using a full size development model and it is found to be satisfactory.

Conference/Seminars

Eighth IAA International Conference on Low-Cost Planetary Missions (LCPM8)

At Goa, India, on 31st August-04th September 2009

for more details: lcpm2009@isro.gov.in, director@prl.res.in, mys@shar.gov.in

A study on the alternatives to Pyrocutters for Deployment Mechanisms

S. Narendra
Spacecraft Mechanisms Group, ISAC Bangalore
E-mail id: naren@isac.gov.in

INTRODUCTION:

Pyro-based release mechanisms are being widely used in today's spacecraft mechanisms for the release of various appendages on the spacecraft. The pyro cutters possess minimum volume/weight, provide instantaneous operation on demand and require little input energy. However the pyro-based mechanisms have the inherent quality of high source shock generation and the feature of not being able to fly the functionally tested pyro mechanism as they are to be replaced after each firing. Also the pyro cutter application for a small satellite would call for greater complexity in terms of the EED package presence and the cost involved would also be high for making a pyro cutter flight worthy.

The emergence of small satellite technologies requiring low shock generation mechanisms has propelled a need to look at other alternatives to the pyro based explosive mechanisms. The development of shape memory alloy (SMA) and paraffin actuator can effectively be used to carry out the functions of the pyro mechanisms, with very less source shock generation and also be able to fly tested mechanisms thus increasing the reliability of the mechanisms. This is the motivation for this paper which addressed the study of the existing alternatives to pyro based mechanisms and a brief comparison of the same is presented.

FUNCTIONAL REQUIREMENTS:

The major requirements of the alternates to the pyro mechanisms are:

- It should be of non explosive type
- Capable of moderate preload and simple in construction
- Capable of functional testing of the flight model
- Low source shock generation
- Amenable to miniaturization

AVAILABLE ALTERNATIVES

Based on the type of actuation incorporated in the release mechanism, the following three prominent mechanisms have been found in literature. They are,

- SMA Based mechanisms
- Paraffin Based mechanisms
- Thermal cutters

Among the three types mentioned above the SMA and Paraffin based mechanisms have been extensively used and lot of developmental activities is in progress. These provide a very wide range of capabilities and can be effectively used to get release mechanisms, having very low source shock and smooth release operations.

In the present study some of the various mechanisms that have been developed using the SMA and Paraffin actuators have been studied and their configuration, specifications and functional details explained. Also a comparison of these mechanisms has been provided, helping one to choose the right type of mechanism based on the merits and demerits of each.

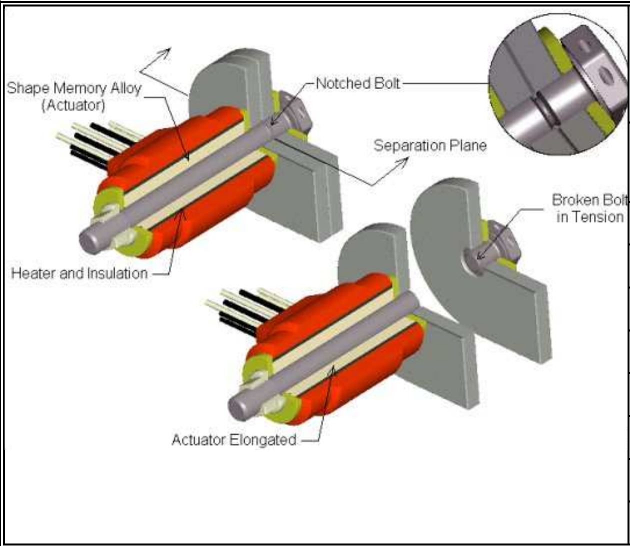
SMA BASED MECHANISMS

Shape memory alloys (SMA's) are metals, which exhibit two very unique properties, *pseudo-elasticity*, and the *shape memory effect*. Arne Olander first observed these unusual properties in 1938 (Oksuta and Wayman 1998), but not until the 1960's were any serious research advances made in the field of shape memory alloys. The most effective and widely used alloys include NiTi, CuZnAl and CuAlNi.

Types of SMA Release Mechanisms

A major focus in the development of low-shock release devices has been the incorporation of Shape Memory Alloys (SMA) as release actuators. The general scheme is to take advantage of the ability of SMA's to recover a parent shape when heated by an electrical current. SMA Materials, such as Nitinol, when heated, can recover a parent shape from a cold deformation involving up to 8% strain. Thus, an SMA actuator may be used to trigger a mechanism that releases a captive element such as a bolt. The basic design requirements for space applications present a challenging problem. The mechanism must be capable of retaining a bolt that is preloaded as required by the launch loads. However, the mechanism must also have sufficient mechanical advantage to allow release by an SMA actuator, which receives a pyrotechnic equivalent firing pulse.
The brief insight into the functioning of the following three mechanism configurations using SMA which are widely used has been presented.

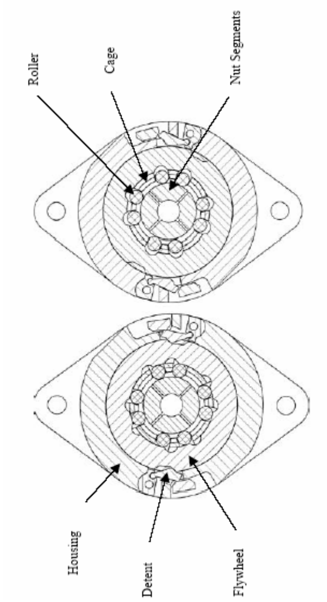
Frangibolt Release Mechanism



TYPE	FRANGIBOLT® ACTUATOR FC2-16-31SR2	
Max Load Support & Release	2200 N	(500 lb-f)
Max Joint Length	4.4 cm	(1.75 in)
Operational Voltage	22 to 36 Vdc	
Min Operating Temp.	-65°C	(-85°F)
Max Operating Temp.	+80°C	(176°F)
Heater Resistance	31 Ω	
Mass	20 g	(0.71 oz)
Power Consumption	25W @ 28Vdc	
Life Cycles	MIN 60 Cycles	

The Frangibolt mechanism developed by TiNi Aerospace consists of a notched fastener, items to secure and bearing washers assembled with the actuator unit as shown in the figure. The actuator unit consists of a SMA cylinder with surrounding heater and insulation. In the normal condition the SMA cylinder is in the compressed state. The notched fastener and the bearing washers are assembled along with the actuator and the assembly is preloaded by tightening the assembly to the prescribed torque. For release function, the heater is powered, which heats the SMA resulting in its increase in length, thus straining the bolt which fractures at the notch releasing the secured items.

QWKNUT Mechanism :(STARSYS Research Corp.)

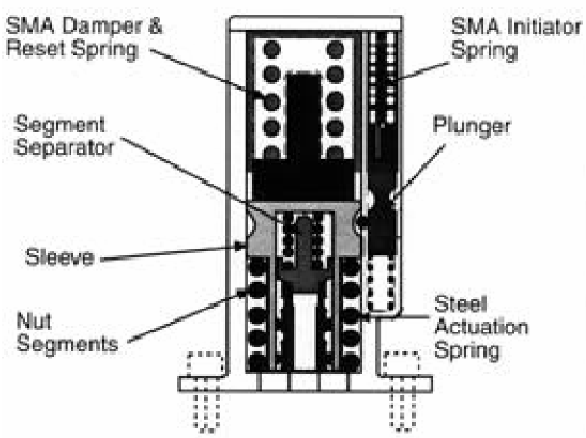


DESCRIPTION	SPECIFICATION	COMMENTS
Thread Size	1/4" – 28 bolt	
Nominal Load Range	500lbf to 3000 lbf	
Ultimate Load Capacity	3750 lbf	
Function Time	< 30 m sec	3.5 amps, 1 circuit, ambient Temp.
Temp. Range	-50C to 60 C	
Random Vibration	35 grms, 3 min/axis	
Vacuum	$1X10^{-4}$torr	Higher vacuum acceptable
Firing Current	3.5 to 5.0 amps for 100 m sec	Higher currents results in faster actuation times
Circuit Resistance	4.0 Ω±0.2Ω	

The Starsys Research Qwknut is a fast acting separation nut for release of loads up to 1500 kgf. The Qwknut uses a conventional segmented nut with a shape memory alloy trigger. The mechanism is capable of resetting in less than a minute.

The Qwknut consists of 4 thread segments which grasp the threads of an attaching bolt, similar to the method used by a standard pyrotechnic separation nut. When a standard pyrotechnic firing pulse is applied to a shape-memory trigger wire, a spring-loaded retaining mechanism is released which allows the thread segments to stroke radially and release the bolt. The Qwknut avoids sliding friction by retaining the thread segments with a series of caged rollers. The cage rollers rotate until the rollers line up with a series of grooves which allow the rollers and the thread segments to stroke radially. The concept thus relies on rolling friction and allows greater functional margins and more predictable functional behavior. Redundant shape memory wires are used. Either or both shape memory wires are capable of releasing the device. Since shape memory is heat sensitive, cut off switches are used to turn off the current to the shape memory wire after its work has been done. This allows repeated use for ground test purposes.

Low Force Nut Mechanism: (Lockheed Martin Aerospace)



The LFN is a small, resettable, reusable mechanism appropriate for preloads less than 1500 kgf. The LFN uses redundant SMA springs as high- force, long- stroke prime mover to release the device. On application of a current the SMA spring expands and generates a force of 10 kgf over 0.25 inches of stroke. This movement releases a spring loaded ball lock latch mechanism which retains a set of 3 thread segments. When the ball lock is released, the thread segments separate radially form the thread of the attaching bolt, allowing the bolt to release. Internal parts are allowed to stroke into the SMA reset spring which serves to mitigate some of the shock generated by the release.

DESCRIPTION	SPECIFICATION	COMMENTS
Thread Size	¼” – 28 bolt	
Nominal Load Range	500 lbf to 3000 lbf	
Ultimate Load Capacity	3500 lbf	
Function Time	< 1.5 seconds	30 amps, 1 circuit, ambient temperature
Temperature Range	-40^0 C to $+60^0$ C	
Random Vibration	10 grms, 3 min/axis	
Shock	8000 G’s	
Vacuum	$1X10^{-4}$ torr	Higher vacuum acceptable
Firing Current	30 amps/1.5 seconds	Higher currents results in faster actuation times.
Circuit Resistance	0.25Ω ±0.5Ω	

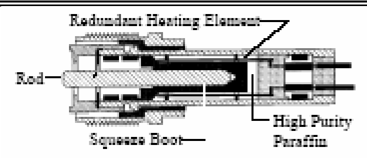
Comparison of Performance of SMA Actuator mechanisms:

DESCRIPTION	FRANGIBOLT	QWKNUT	LFN
Preload Capability (N)	220 kgf	1500 kgf	1400 kgf
Shock (g levels)	800 g	< 100g	400 g
Mass (g)	20 grams	200 grams	250 grams
Release Time (ms)		35 ms	62 ms
Reset (Yes/No)	refurbish	yes	yes
Pyro Pulse	No	yes	No

PARAFFIN BASED MECHANISMS

These release mechanisms make use of the paraffin actuators as the prime movers. The heart of the mechanism consists of a paraffin actuator. The figure shows the cross section of paraffin actuator developed by STARSYS. The actuator makes use of the constrained volumetric expansion of a highly refined paraffin wax at a well – defined transition temperature to produce large hydrostatic pressure and perform work. The hydrostatic pressure developed is translated to actuator extension through a “squeeze boot”. The actuator can be functioned repeatedly.

Specifications of (IH- 5055 type Actuator From STARSYS)

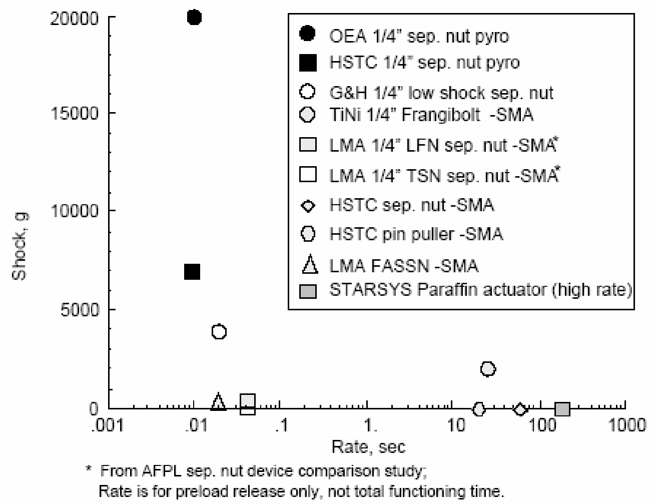


c. Starsys HOP actuator; pre-release.

DESCRIPTION	SPECIFICATION
Mass	54 gms.
Power/Voltage	10 watts @28V
Response time	210 secs
Output Force	222.4 N
Output Stroke	1.27 cm
Operating environment	-180 to 115o C
Lifetime	1000+ cycles
No-fire temperature	80^0 C
Mounting configuration	Ferrule / Flange
Wiring / insulation	4 leads 26 AWG./ TEFZEL

Comparison of Mechanisms

Functional Requirement	Explosive Mechanisms	Non Explosive Alternate mechanisms	
	Pyro cutter mechanisms	SMA based actuators	Paraffin Based mechanisms
Source Shock Generation	Very high (20000 to 6000 g shock levels)	Moderate to low source shock (4000g to 0g)	Low source shock generation (100g to 0 g)
Preload capability	Very high	High to moderate	High to moderate
Power requirement	Low	Low	High
Out gassing	Moderate to Nil	Nil	Nil
Time for Actuation	Low (msecs)	Low (msecs)	High (sec-min)



Functional Shock Vs operational Rates of various mechanisms

CONCLUSIONS

A brief introduction to the alternatives available to the pyrotechnic mechanisms have been presented. The paraffin actuator based and the SMA based release mechanisms provide an attractive alternative to the pyrocutters. The paraffin actuators are really advantageous when a high actuator force is required and very low source shock is required. The SMA based mechanisms provide for a moderate preload requirement and the actuation time and power requirements are comparable to that of the pyro based mechanisms.

However the limitations of the same like higher power requirement and greater actuation time in case of the paraffin actuators and the moderate to low force generation of the SMA based actuators are to be accounted in the early design stage.

REFERENCES:

- Report on Alternative Devices to Pyrotechnics on Spacecraft – M.Lucy, R.Hardy, E. Kist, J.Watson, S.Wise National Aeronautics and Space Administration, Langley Research Center, Hampton, Virginia
- Development of Shape Memory Alloy (SMA) Actuated Mechanisms for Spacecraft Release Applications SSC99-XI-7 13th AIAA/USU Conference on Small Satellites
- Development and Transition of Low-Shock Spacecraft Release Devices for Small Satellites SSC00-XI-5 , 14th Annual/USU Conference on Small Satellites
- Product catalogue of STARSYS

Symposium on 'Autonomous vehicles', February 13th, 2009

The symposium on 'Autonomous Vehicles' was held on 13th February 2009 at ISRO Satellite Centre, Bangalore. The symposium was inaugurated by Dr. TK Alex, Director, ISAC. The symposium proceedings was released on this occasion by Sri Manjit Singh, DS, BARC, Mumbai(1). Invited Lectures were given by the following eminent personalities; Dr. Alok Mukherjee, DRDO, Pune (2), Sri. K Ramesh, CAIR (3), Prof. CS Kumar, IIT, Kharagpur (4), Prof. Ashish Dutta, IIT, Kanpur (5), Dr. Jagannath Raju, M/S Systemantics, Bangalore (6), Dr. PK Pal, BARC (7), Dr. Vishwas Udpikar, M/S Wavelet Group, Pune (8), Dr. Karthikesan, VSSC, Valiamala (9).

The invited lectures were very well received by members. There was a good exchange of information through these invited talks and subsequent interactions. This symposium has opened up avenues for collaborative efforts with the working groups in the above organizations for further development.

We invite you to send technology news, technical articles, members news and suggestions/comments on e-newsletter and the web contents to Chief Editor to improve the newsletter. The technical articles may be limited to 400 words only in MS Word format with two photographs. The direct extracts from references may be avoided. Kindly provide your e-mail & mail address to enable us to contact you.

enewsletter@insarm-bangalore.org
www.insarm-bangalore.org