SALT TECHNICAL OPERATIONS

PROJECT STATUS REPORT

TITLE: STATUS REPORT: TRACKER UPGRADE PROJECT

BOARD MEETING # 37, MAY 2015

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LIST OF ACRONYMS AND ABBREVIATIONS

Abbreviation	Description
CDR	Critical Design Review
CER	Concept Evaluation Review
COTS	Commercial Off The Shelf
CoC	Certificate of Conformance
ECR	Engineering Change Request
FAT	Factory Acceptance Test
FDR	Final Design Review
FEA	Finite Element Analysis
PDM	Product Data Management
PDR	Preliminary Design Review

1 Project Status Summary

The Tracker Upgrade project has successfully completed the Y-Drive Upgrade Stage of the project by passing the FDR and delivering the complete installation kit to SALT. The kit contains all the completed subassemblies as well as all the documents required to do the installation at SALT.

Subsequently, Stage 2 of the project, Rho-Upgrade, has also been successfully completed by passing FAT exceptionally well. FDR was passed and delivered the complete installation kit to SALT early in March 2015. The kit contains all the completed subassemblies as well as all the documents required to do the installation at SALT. This delivery was finally made 2.8 months later than planned mostly due to poor manufacturing supplier performance, resources allocated to other projects like RSS delaying FAT, and the Xmas holidays.

Stage 3 of the project was commenced the end of February 2015 and entails the Hexapod Upgrade. The concept design was culminated in the CER passed the middle of April 2015, approximately 2 weeks ahead of schedule. So far, recovering the original 2.8 month delay to 2.3 months.

During the concept phase structural testing was conducted on the Hexapod Ball Joints that were suspected to have a high probability of failing in the current SALT configuration. The tests proved conclusively that the probability of failure is remote as well as supplying allowable design loads for the Ball Joints. Also proved are that the upper Ball Joints B1 and B 3 have been operating outside of their design limits and intent for a long time. Some seal damage is suspected.

Please see Table 1 for the completion status of the Hexapod Upgrade stage of the project.

Table 1: Hexapod Upgrade Completion status.

Item	% Complete	Date Complete	Responsible	Comments
Rho-Drive FAT	**100%**	**Feb 2014**	**Project Team**	**2.8 Month delay caused by manufacturing, resource starvation and Dec. holidays.**
Rho-Drive FDR	**100%**	**Early March 2014**	**Project Team**	**2.8 Month delay caused by manufacturing, resource starvation and Dec. holidays.**
Hexapod CER	**100%**	**April 2015**	**Raoul, Grant, Wouter, Eben, Keith**	**Completed. 2 weeks ahead of schedule.**

Hexapod Detail Design Phase	**15%**	**July 2015**	**Raoul, Grant, Wouter, Eben, Keith**	**Started.**
Hexapod PDR	**20%**	**June 2015**	**Project Team**	**Planned.**
Hexapod CDR	**10%**	**July 2015**	**Project Team**	**Planned.**
Hexapod Data Pack and Manufacture	**0%**	**Aug 2015**	**Raoul, Grant, Wouter, Keith, Eben, Vic**	**Planned.**
Hexapod FAT	**0%**	**Nov 2015**	**Project Team**	**Planned.**
Hexapod FDR	**0%**	**Jan 2016**	**Project Team**	**Planned.**

2 Technical Solution

During the pre-study, and confirmed during the Hexapod Upgrade concept design phase, it was found that the critical components are the Hexapod Ball Joints as well as the Hexapod motors, gearboxes and clutches. The Hexapod Upgrade concept design solution consists of a ball joint load relief system called HAGS (Hexapod Anti-Gravity System) and replacing the Hexapod motors/gearboxes/clutches with Harmonic Drive Systems. The drive motor chosen is a harmonic drive (new technology) which is much lighter, stronger and requires less current, cooling and maintenance as well as replacing the current clutches and gearboxes. Due to maintenance and telescope off-line costs reasons, the decision was also made to replace the X and Y drives with these motors.

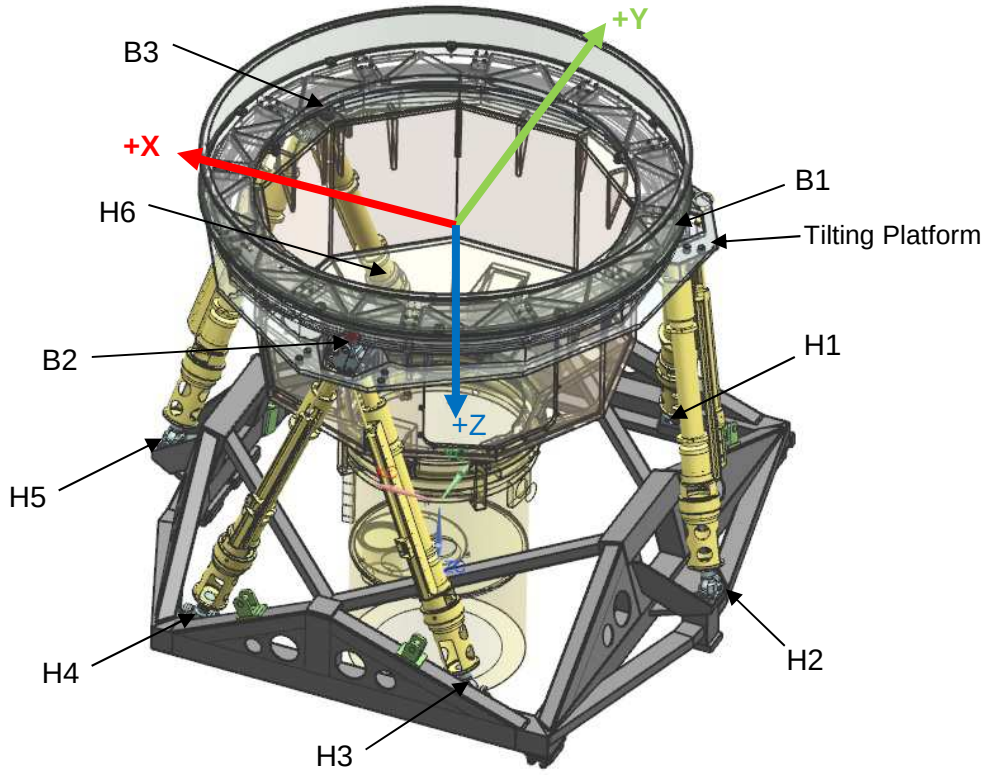
From the Figures below it can be seen that the HAGS for Ball Joints B1 and B3 are different to that of B2. As the Hexapod is positioned on the tracker beam mounted at an angle of 37 deg. to the vertical, the major component of the load experienced by B1 and B3 acts in the XY plane parallel to the Tilting Platform. The Tilting Platform also pivots around B1 and B3 causing the loads on B2 to act downwards in the Z direction. B1 and B3 are the highest loaded Ball Joints and the majority of the load is carried transversely and not axially as Ball Joints are designed to do.

By using HAGS to relieve the loads on the ball joints to Scheaffler/INA specified limits, will allow the ball joints to operate as they were designed, instead of operating as plain bearings as they currently do.

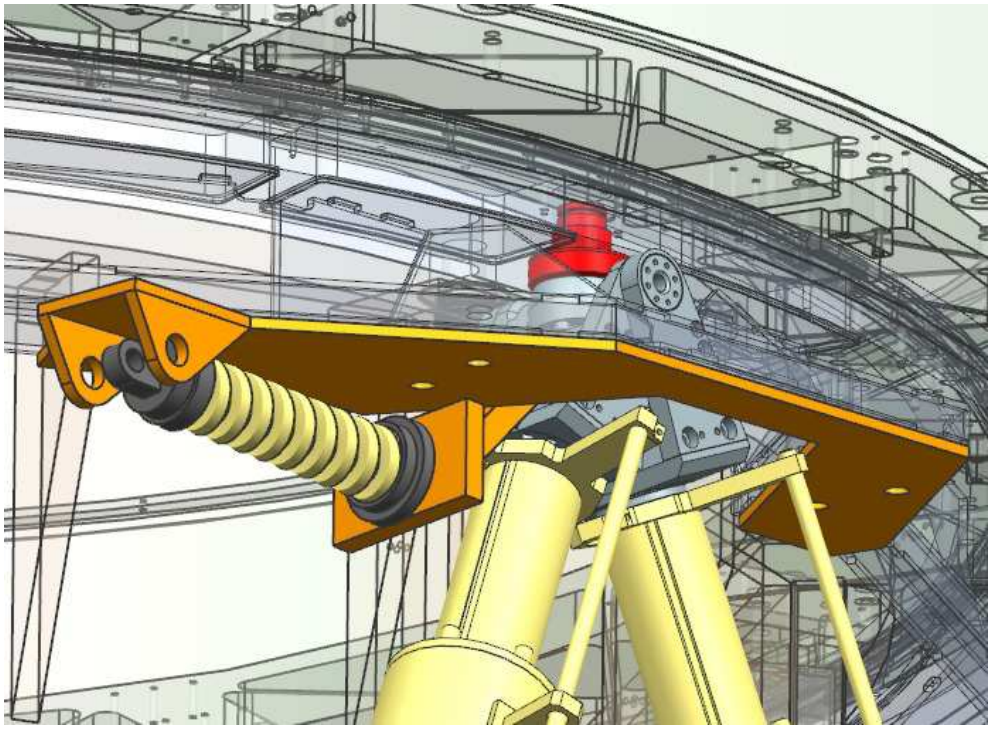
HAGS will give us the following benefits:

1. The ball joint will operate as designed with lower friction and “stiction”. Possible improvement during tracking.
2. The seals will last longer and not allow dirt/dust to enter the ball joint.
3. The ball joint will be so lightly loaded that they will effectively have “infinite” life.
4. Loads to be transferred to some of the Hexapod fork components will be lower, reducing the possibility of fatigue failures.

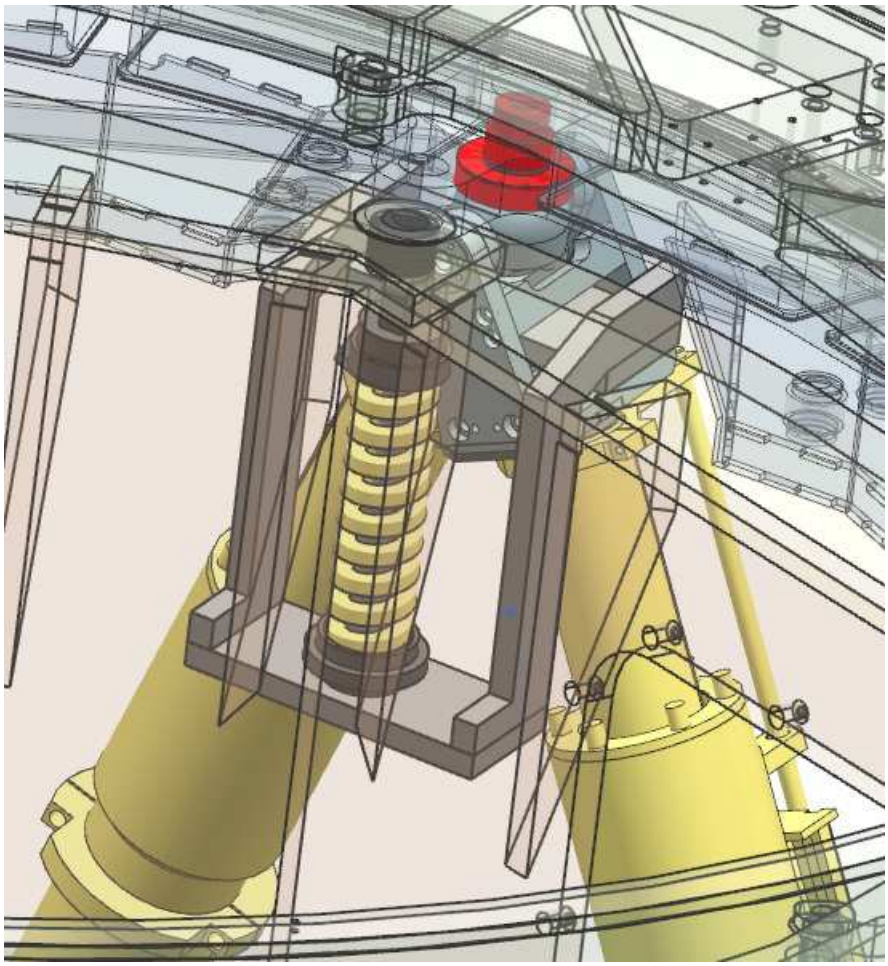
All mechanical components have a minimum safety factor of 1.5 on yielding. The ball joints were tested to 1.2 times the operational load. FAT will be conducted to ensure that all performance specification parameters such as accuracy, track and slew speeds are met or exceeded.



Hexapod Isometric View

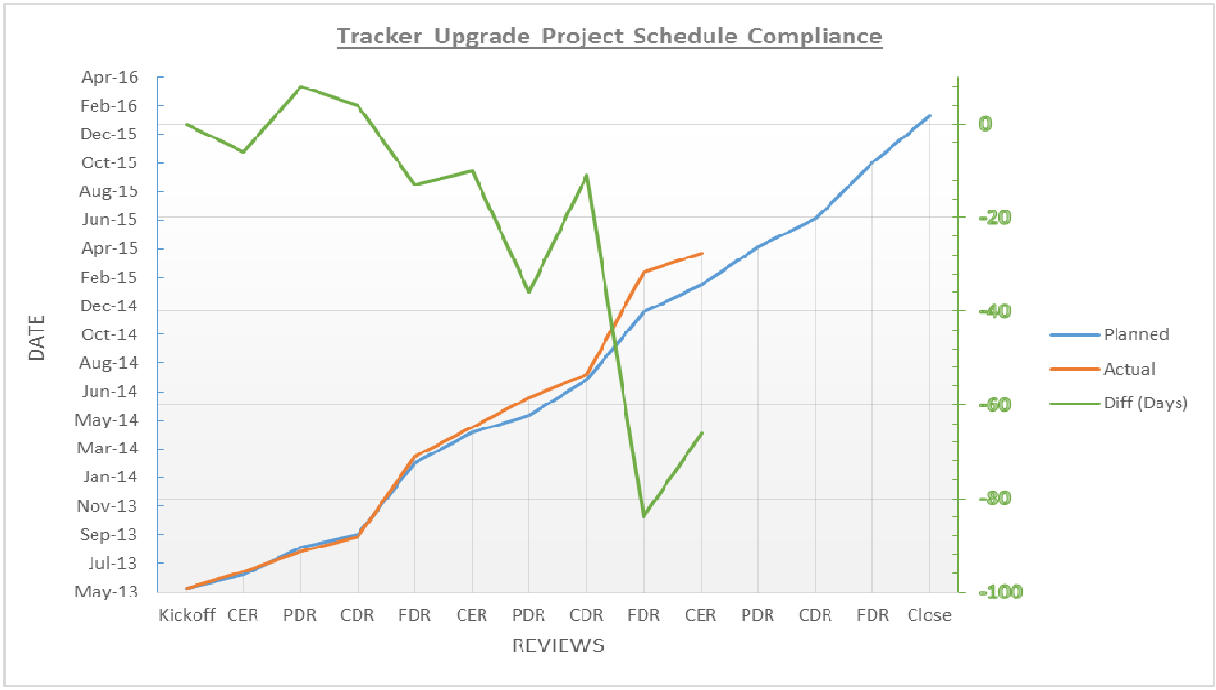


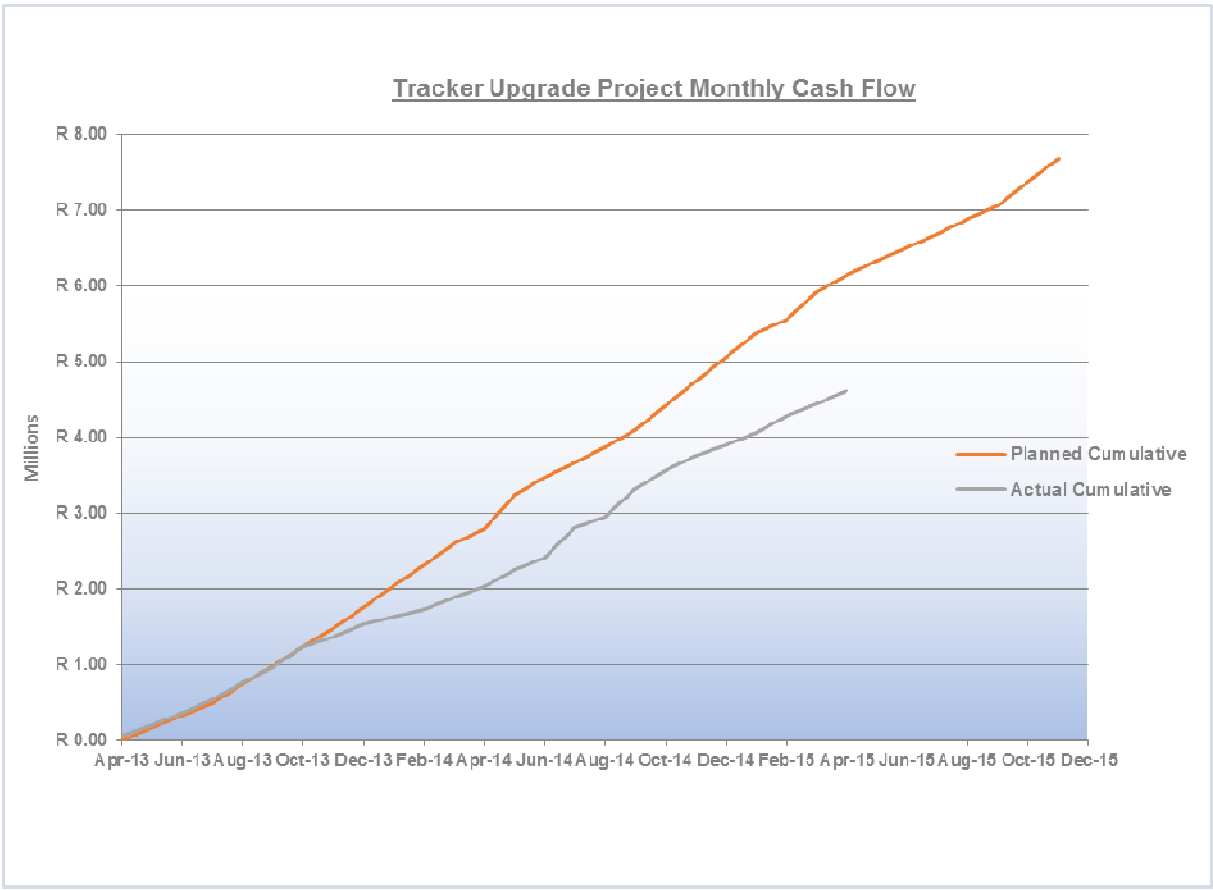
HAGS Concept on B1 and B3



HAGS Concept on B2

3 Schedule and Cash Flow Compliance





4 Conclusions

Stage 1 and Stage 2 of the Tracker Upgrade Project have been completed successfully and have passed all FAT, technical and project reviews. Complete 'Installation Kits' are currently in the SALT store ready for installation and commissioning.

Stage 3 of the project was commenced the end of February 2015 and entails the Hexapod Upgrade. The concept design phase was culminated in the CER passed the middle of April 2015, approximately 2 weeks ahead of schedule. Recovering the original 2.8 month delay to 2.3 months.

Ball Joint structural tests proved conclusively that, as currently being utilized on SALT, the probability of failure is remote. These tests also supplied and confirmed valuable design data and limitations. In addition, also proved are that the upper Ball Joints B1 and B3 have been operating outside of their design limits and intent for a long time.

Currently, the project is within budget with a cash flow below planned. Lower than planned cash flow is indicative of the project delay as some of the man-hours were directed towards other projects. The project duration will increase and the man-hours will be burnt towards the end of the project. All effort will be put in, to recover as much as possible of this delay. However, not all of it will be recovered in the remaining 10 months of the project.

5 Lessons Learnt to Date

- Pre-Project definition and documenting of processes & procedures such as for Project Management, Design and Configuration Control are essential for a successful project.
- Training of the project team in these processes, if they are not already working this way, is very important.
- The manual Configuration Control and PDM (Product Data Management) system being used for the project is tedious, time consuming and error prone. It is suggested that a real PDM/PLM system be implemented at SALT/SAAO.
- Design and FEA (Finite Element Analysis) collaboration should be improved. FEA without hand stressing is not worth much.
- Over a project duration of more than a year the current Sutherland team cannot supply more than 1 resource to support any one project.
- Formal Incoming inspections are crucial for quality and to reduce major delays during assembly.

- Industrialisation Phase Process should be followed to link aspects such as incoming inspection, data pack checking/approval, FAT and the procurement process.
- Data Pack Duration KPI's:
    - Stage 1: Data Pack creation, checking, approval, quote and order on 21/10/2013 was 788 man-hours divided by 110/2 drawings = 14.3 hours per drawing.
    - Stage 2: Data Pack creation, checking, approval, quote and order. CDR 5/8/2014 orders 21/10/2014 was 1350 man-hours divided by (102+65)/2 drawings = 16.2 hours per drawing.
- Material availability (grade and form) from multiple suppliers are to be checked and confirmed at PDR stage of design.
- Manufacture was estimated at 6 weeks but 12 weeks seems more realistic when including all the other procurement aspects. Ensure orders are in at least 12 weeks before Xmas shutdown.
- Paying a levy for high quality manufacturing and inspection suppliers probably saved a minimum of 3 weeks during incoming inspection and assembly.
- Preparation and simulation of FAT to improve, to reduce wasted time and infant mortality. FAT commissioning/planning phase to be added to FAT schedule.
- By spreading the limited project resources over a number of projects, guarantees them all to fail.
- During Rho-Upgrade FEM was introduced much earlier in the design process (even before PDR) and was used concurrently in the design. This worked well and good correlation was found with the hand calcs. Both were used to check the other. It did however, highlight the need to used interim revision numbers between maturities eg B, B1, B2, B3……..,C. Also highlighted is the need to keep the part description short eg. 1516AD2000_B Drive sys, only the number and 1 or 2 well-chosen words. Our servers cannot cope with long part names and because of the computing intensity we cannot run FEM on the server. A PLM system syncing with servers in CT and Sutherland will resolve these issues.
- Our design process requires 3D model checking even before PDR, but due to unplanned OPS events the Sutherland Team was only able to complete this 1-2 weeks before CDR. Although the suggestions were excellent and extremely valuable they should have been given earlier in the design phase such as during or just after PDR. It is suggested that a Sutherland Team Leader be seconded to the project for the Hexapod Upgrade.
- Due to the large percentage of welded assemblies in the Rho Upgrade lower quality manufacturing and inspection suppliers were used costing the project at least 2 months in late/reworked deliveries.

- Develop alternative coating/surface finishing possibilities both from supplier and material point of view will reduce possible delays during manufacturing.