# StarBugs: a New Technology for Galaxy Survey Instruments

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## Starbugs

**Starbugs** are a pair of concentric piezoceramic actuators that carry an optical fibre payload. When a varying voltage is applied to the Starbug, it is capable of "walking" across a surface, allowing **precise positioning** (within a few microns). Figure 1 shows a schematic representation of Starbug motion.

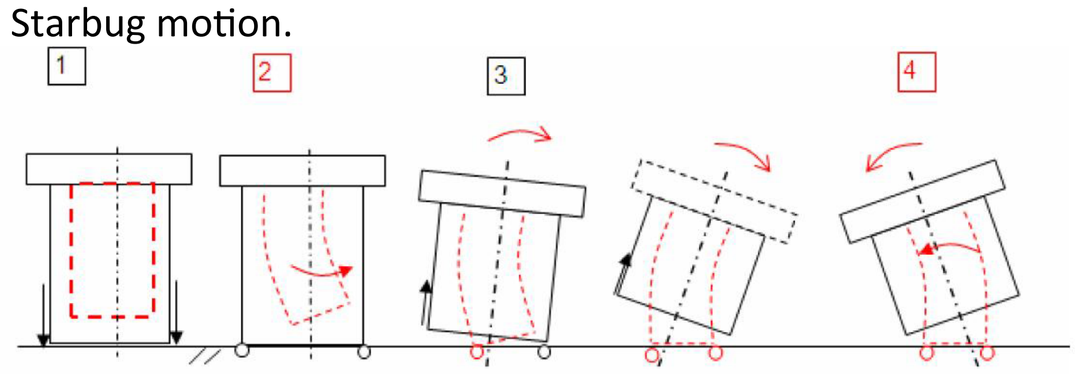



Figure 1: Starbug "walking" by contraction and bending of concentric piezoceramic actuators

## Starbug Fabrication and Testing

As the telescope moves, Starbugs hold their position by means of vacuum adhesion, which requires **precise polishing** of the piezoceramic surface. The Starbug polishing rig and Starbug performance testing rig are shown in Figure 3, upper panels. To move the optical fibres onto their desired targets, **high-voltage electronics** send (anti-)symmetric waveforms to opposite sides of each Starbug. A packaged Starbug with electronics, vacuum, and fibres, along with the high-voltage electronics board, is shown in Figure 3, lower panels.

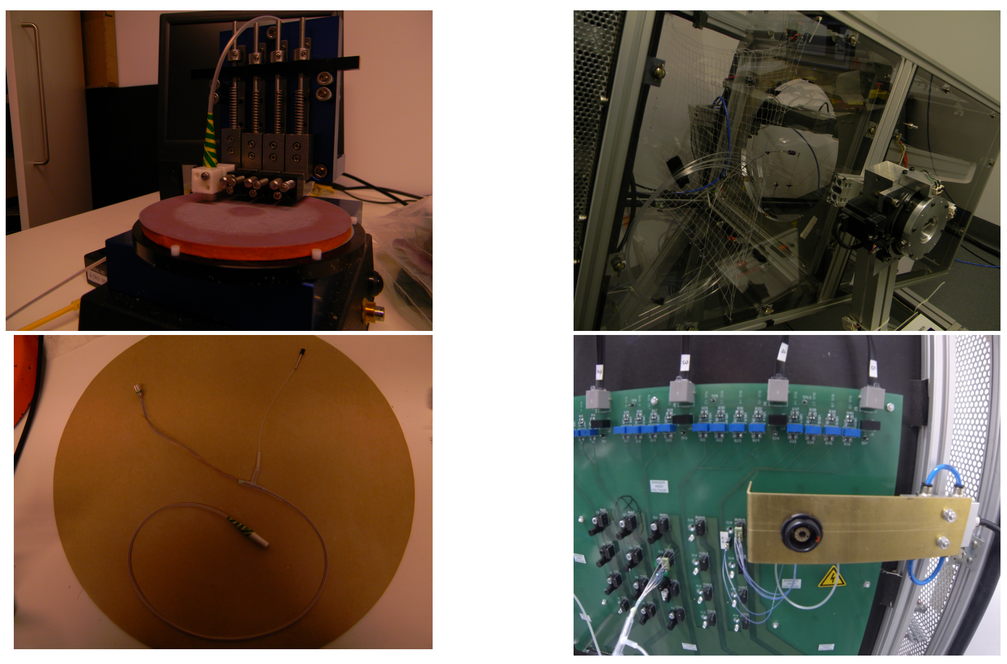
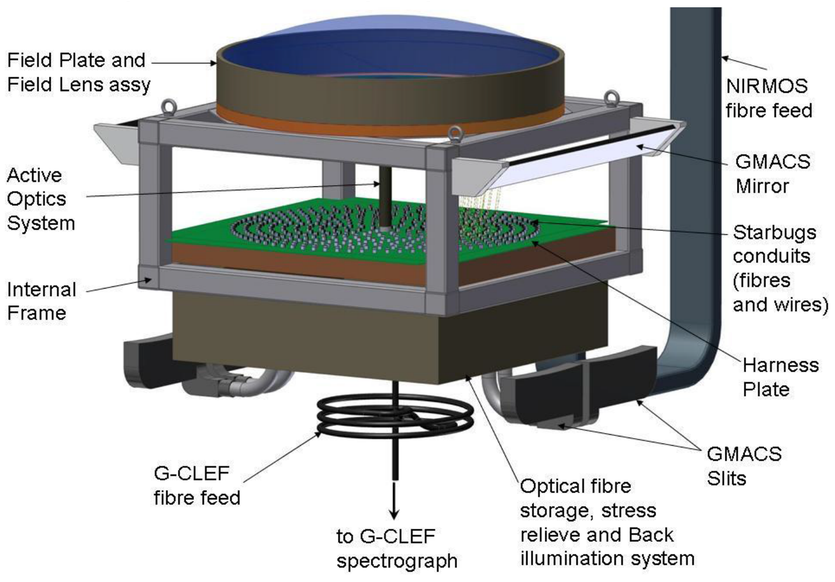


Figure 3: Starbug polishing rig and performance test stand; a fully-packaged Starbug and the high-voltage electronics board

## The Future: MANIFEST on the GMT

MANIFEST is the **Many-Fibre Positioner System** that will allow simultaneous feeding of several GMT instruments. It will make use of several times more starbugs than TAIPAN, allowing observation of even more objects with far greater precision -- for survey science, MANIFEST will at least **double the power** of the GMT. Figure 4 shows a schematic drawing of MANIFEST, while Table 1 (right) compares the survey capabilities of GMT + MANIFEST with other 30 m-class telescopes and their proposed instruments.




## A Transformative Technology

When an array of Starbugs are placed at the focal surface of a telescope, they can simultaneous gather light from many independent objects. Software controls allow **parallel positioning** of every Starbug, reducing reconfiguration time of the field from tens of minutes to tens of seconds. Figure 2 shows ten Starbugs in operation.

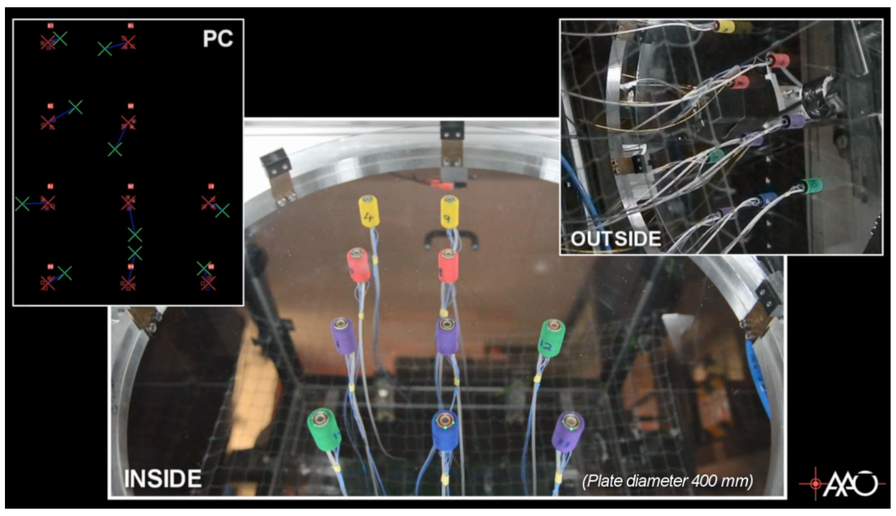



Figure 2: Ten Starbugs being position on a prototype glass field plate

## TAIPAN Components

TAIPAN is a **pathfinder instrument** for the MANIFEST fibre-position system that will be installed on the Giant Magellan Telescope in ~2020. TAIPAN will allow observations with up to **300 Starbugs** on the UK Schmidt Telescope at Siding Spring Observatory starting in ~2015. Key subsystems of TAIPAN include:

- StarBugs and associated electronics
- Glass field plate for Starbug mounting
- Precision Starbug metrology system
- Object acquisition & guding system
- Telescope interface and calibration system
- Fibre control and data acqusition software system
- TAIPAN Spectrograph

## TAIPAN Survey Objectives

TAIPAN will obtain R = 2300 visible band **spectra from hundreds of thousands of Southern sky galaxies** in the magnitude range $14<r<18$ at SNR=1-7 over five years. TAIPAN will also obtain a nearly complete (>99%) census of Southern sky stars in the magnitude range $5.7<v<12$ at SNR=100. Finally, TAIPAN will **demonstrate the feasibility** of Starbug technology for fibre positioning, reducing risk and cost to the future MANIFEST instrument.

## TAIPAN Science Goals

TAIPAN will provide a **measurement of $H_0$** to within 2% (with a goal of 1%). TAIPAN galaxy redshift determinations can improve the measured accuracy of the local growth rate by a factor of 2, resulting in stronger tests of General Relativity, while peculiar velocity measurements can produce similar gains using larger-scale modes. TAIPAN will **enable studies of galaxy evolution** in addition to cosmology, and will engage in the stellar survey (FunnelWeb) as well.

| Telescope + Instrument | Diam. (D) | Tel. Field ($\phi_T$) | Inst. Field ($\Omega_I$) | $D^2$ | $D^4$ | $A\phi_T$ | $A\Omega_I$ |
|---|---|---|---|---|---|---|---|
| GMT + MANIFEST | 25.4m | 20' | 314' | =1 | =1 | =1 | =1 |
| TMT + WFOS | 30m | 20' | 100-200' | 1.4 | 1.9 | 1.40 | 0.35-0.7 |
| E-ELT + DIORAMAS | 42m | 10' | 46' | 2.7 | 7.5 | 0.68 | 0.40 |

Table 1: A Comparison of GMT + MANIFEST with other 30 m-class telescopes and their proposed instruments

Figure 4 (at left): a schematic drawing of MANIFEST