The Space Dynamics Laboratory (SDL) has developed a novel, high performance, linear motion translation stage mechanism called the Double Arm Linkage, precision Linear motion (DALL) carriage (patent pending).

The DALL carriage is applicable for systems requiring a highly linear motion (low shear) and/or low angular deviation (low tilt) over a travel range of up to a few centimeters. It is a rugged device and can tolerate harsh operating conditions.

Possible applications include:
- Precision optical positioning
- FTS (Fourier Transform Spectrometer) moving mirror stages
- Applications requiring low shear & tilt in a linear motion stage

**DALL CARRIAGE DESIGN**

**DOUBLE ARM LINKAGES FOR LINEAR MOTION**

The DALL mechanism achieves linear motion by using two sets of double arm linkages. Each linkage consists of two arms, connected by flexure hinges with parallel rotation axes, that link the base to the carriage. This arrangement constrains the motion of the carriage to a plane perpendicular to the rotation axes of the hinges. The following illustration shows that the hinges and associated arms constrain the motion of the carriage to the blue and red planes, respectively. The intersection of the mutually orthogonal red and blue planes defines the axis of travel, with the motion of the carriage ideally constrained to this line.

**BENEFITS**

**HIGH PERFORMANCE**

Through its range of motion, the DALL carriage stage design provides for very low shear and tilt (very small lateral deviation from linear motion and very small angular variations). It provides high off-axis stiffness with smooth, frictionless motion in the travel direction.

**HARSH ENVIRONMENT TOLERANCE**

As a monolithic structure, there are no joints to slip and no CTE (coefficient of thermal expansion) mismatch issues. The structure provides:
- Shock resistance
- Vibration tolerance
- Wide temperature operation, including cryogenic

**NO ASSEMBLY, NO ALIGNMENT**

The monolithic design completely eliminates stage assembly and alignment, which are typically costly and time consuming procedures. Once machined, the carriage does not require any adjustments.

**REDUCED COST, COMPLEXITY, AND RISK**

The simple monolithic design reduces complexity and increases reliability, lowering overall system risk and cost. This is particularly important for space or other demanding environments.

**MONOLITHIC CONSTRUCTION**

The carriage is machined as a simple and rugged monolithic structure from one piece of material, including flexural elements.
OPTIMIZATION FOR SPECIFIC APPLICATIONS

The DALL carriage can be designed to maximize specific performance requirements for any given application. Design variables and trades include:

- Travel length
- Shear
- Tilt
- Off-axis stiffness
- Size
- Weight
- Load capacity

Various actuators are possible to accommodate different application requirements.

PROTOTYPE PERFORMANCE

FTS APPLICATIONS

SDL has designed, manufactured, and tested a first generation prototype of the DALL carriage. This system was designed for concept demonstration and verification, with a specific application as an FTS moving mirror stage. The DALL carriage design provides for high modulation efficiency over wide wavelength ranges in flat or corner cube mirror FTS designs, due to low shear and tilt, respectively.

It is expected that overall system performance will be improved in follow-on systems by applying improved machining techniques.

The following measured values were achieved on the first prototype.

SHEAR (Lateral deviation from linear motion)
- < 0.3 µm over ± 0.5 cm travel range (0.5 cm⁻¹ resolution)
- < 0.75 µm over ± 1.0 cm travel range (0.25 cm⁻¹ resolution)

Values are far below the 3 µm corner cube FTS performance goal.

DALL PERFORMANCE – SHEAR DATA

TILT (Angular variation)

Azimuth:
- 1 arc second over ± 0.5 cm travel range (0.5 cm⁻¹ resolution)
- 2 arc second over ± 1.0 cm travel range (0.25 cm⁻¹ resolution)

Results are very promising, compared to 1 arc second flat mirror FTS performance goal.

DALL PERFORMANCE – TILT DATA

Note: Elevation tilt data (not shown) for this prototype shows greater tilt values than the Azimuth tilt data. This is due to known manufacturing errors.

SDL’s first prototype has demonstrated the manufacturability of the monolithic DALL stage design and has shown high performance. Increased performance is expected to be readily achievable for both shear and tilt in future design iterations. This expectation is based on modeling and design refinements and known improvements in fabrication techniques.