PFIS – Articulation Mechanism

SPECIFICATION
SALT-3130AE-0013

VERSION 1
16 February 2003

1. Scope

1.1 Identification

This document covers the design of the Articulation Mechanism for PFIS. In it are detailed the specifications, operating criteria and details of the design.

1.2 System Overview

The Articulation Mechanism is the mechanism that articulates the camera from 0 to 100 degrees during grating spectroscopy mode operations.

1.3 Document Overview

This document first details the functional (science) requirements, then the technical (physical) requirements and then details the design of the mechanism and sub mechanisms.

2. Referenced Documents

SALT-1000AS0007  SALT System Specification
SALT-1000AA0030  SALT Safety Analysis
SALT-3120AA0002  Grating and Filter Specification Document
SALT-3170AE0005  PFIS Safety Analysis
SALT-3140AE0015  Interlock Specification and Design Document
SALT-3140AE0020  Actuators and Sensors
SALT-3130AE0002  PFIS Mechanical Overview
SALT-3130AE0003  PFIS Pneumatics Overview Document
3. Science Requirements

3.1 Schematic Diagram

The geometry of the camera is assumed to be a 300mm ID tube (304mm OD), 550mm long. The articulation Axis is at (–535,0) and the camera is 200mm from the articulation axis.

3.2 Geometry

The geometry of the camera is assumed to be a 300mm ID tube (304mm OD), 550mm long. The articulation Axis is at (–535,0) and the camera is 200mm from the articulation axis.

3.3 Speed into Position and Duty Cycle

Time to rotate 100 degrees: ~20 seconds
Time to clamp and unclamp: ~2 seconds
No. of angle changes per evening: ~20
3.4  Positional Repeatability and Alignment

The accuracy of positioning of the front and back of the camera are as follows:

During observation:
Translations:
X, Y, Z: 5 micron

Repeatable Positioning:
Translations:
X, Y, Z: 15 micron

Absolute Position:
Translations:
X, Y, Z: 100 micron

Concentricity of Z axis and grating rotation axis: machine tolerance (100 microns)

3.5  Operational Modes

The mechanism must be able to articulate the camera to discreet positions, 0.5 degrees apart between 0 and 100 degrees of articulation.

4.  Technical Requirements

4.1  Interfaces

The articulation bearing is attached to the PFIS structure on the same axis as the grating rotation axis.

The grating rotation mechanism is attached just above the articulation bearing.
The grating frame is attached to the articulation frame on the sides of the camera.
The PFIS camera is cradled in the articulation frame.
The filter mechanism is attached to the articulation frame.

4.2  Physical Characteristics

4.2.1  Mass Estimate

The Mechanism currently has an estimated mass of 17.1kg. The current estimate breakdown is given in the parts list appendix.

4.2.2  Materials used and Properties

The baseline choice of material will be aluminium. The detent strip will be made of invar as it is directly attached to the I-beam on the PFIS structure.
4.3 Geometric Requirements

4.3.1 Position of Mechanism and Envelope
The articulation bearing axis is along the z-axis at x=-535, y = 0.
The cam rollers run on the I-beam, at a radius of 650mm.
The articulation mechanism cradles the 304mm OD camera tube, 7mm off center (away from the direction of rotation).
The mechanism must be able to rotate from 0 through to 100 degrees.

4.4 Positional Tolerances
The positional tolerance of the optical elements is detailed in section 3.
The articulation mechanism will provide repeatable positioning of the camera to 15 microns. The absolute positioning – as a result of I-beam flatness and bearing concentricity will be to 100 microns.

4.5 Drive Requirements

4.5.1 Maximum Heat and Power Output
The Power and temperature requirements of the SALT Telescope as set out in SALT System Specification Section, 5.3.2.5 shall be adhered to.

4.5.2 Encoding
All motor driven stages will have absolute encoding while pneumatic actuators will only have position sensors at their end positions. The motor drive stage will have encoding and soft limits used for positioning while hard limit switches will stop the stage from going outside of its operating range. The articulation mechanism will have full range quadrature encoding with an accuracy of 15microns.

4.6 Safety
All mechanisms shall be designed such that electrical or software malfunctions cannot damage any hardware. Pneumatics should hold their position during a power failure and solenoids should fail in a clamped position.
5. Description of Design

5.1 Layout

5.1.1 Basic Overall Layout

The drive and detent sub-assemblies are mounted off one of the cradle beams of the articulation mechanism.
5.1.2 Drive and Detent

Drive Assembly

Fail Safe Brake

High-Torque Stepper Motor

Gear Box

Pinion Gear

Flexible Rack Welded to Angle section

Mount Plate welded to Structure

Drive Sub Assembly

Detent Sub assembly
5.1.3 Bearing and Cam Roller

Cam Rollers
5.2 Speed of Motion

The motor has a rated speed of 10 rps at 1.06 Nm torque. The torque out of the 16:1 gearbox is thus ~13.6Nm. At a cruise speed of ~10rps, the camera will be able to move its full range of travel in 20s

<table>
<thead>
<tr>
<th>Power Windings (1s)</th>
<th>Release Brake (1s)</th>
<th>Insert Detent (1s)</th>
<th>Apply Brake (1s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Release Detent (1s)</td>
<td>Rotate 100 Degrees (20s)</td>
<td>Power Windings Off (1s)</td>
<td></td>
</tr>
</tbody>
</table>

5.3 Motion Control

5.3.1 Articulation Rotation

Motion
The stepper motor (KM063F13) provides the motion by means of a 16:1 gear box rotating a pinion gear onto a rack mounted on the inside of the articulation rail. This drive system is low precision and is designed to get the camera to within 0.5mm of a detent position.

A pneumatic driven detent (ADVU-63-10-A-P-A) provides precise positioning by driving a wedge detent into the detent rail on the inside of articulation rail. The detent positions the camera to 15 micron repeatability at one of the 200 articulation positions (every 0.5 degrees).

Encoding
An angle encoder provides angular encoding of the articulation to 3.5 arc seconds precision. This encoder has a built in index mark. The detent inserted position is registered by a position sensor (SME-8-K-LED-24).

5.4 Control Interlocks

In order to allow the detent to position the camera (with the motor off) while ensuring that the camera is always under control, the following series of interlocked actions need to be adhered to.

Detent

There are three allowed detent states.

1) Free when the detent is out and the camera is free to articulate.
2) Caught, when the detent is inserted far enough to prevent articulation but is not yet fully inserted
3) Positioned, when the detent is fully nested in its slot and the camera is at its final precise position.

Motor

Then the motor which drives the motion has three allowable states.

1) Rotate
2) Holds (with windings on)
3) Free (windings off)

Brake

The brake can be either on or off, it is a fail-safe brake and thus requires power to be released. We thus want it clamping whenever we are not trying to move the articulation mechanism so as to minimize heat dissipation.

Order of events in normal operation

This is the order of events to operate the articulation mechanism – move from one articulation angle to another.

At rest the mechanism will have the detent positioned, the motor free and the brake clamped

1) Power windings
2) Release brake
3) Retract detent (wait for signal from sensor S1)
4) Rotate motor till camera is within 0.5mm of required position
5) Insert detent (wait for signal from sensor S2)
6) Turn motor windings off. (wait for signal S3)
7) Clamp Brake

Additionally there is an interlock to the Etalon Mechanism to ensure that the camera does not articulate while the Etalons are inserted

6. System Air, Power & Signal Requirements

6.1 Air
The maximum air usage for the 1 second it takes to insert the detent would be 2 l/min at 6 bar.

6.2 Electrical Power

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Power</th>
<th>Voltage</th>
<th>Max Duty Cycle</th>
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<tbody>
<tr>
<td>Nema 23 Stepper Motor</td>
<td>1</td>
<td>3.5A</td>
<td>24</td>
<td>24/day, 8/hour</td>
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<tr>
<td>Fail Safe Brake</td>
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<td>.25A</td>
<td>24</td>
<td>24/day, 8/hour</td>
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<tr>
<td>Solenoid Valve for Pneu</td>
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<td>.55W</td>
<td>24</td>
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6.3 Logic

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Resolution</th>
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<tbody>
<tr>
<td>Vane Switch</td>
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<td>10μm</td>
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<tr>
<td>Angle Encoder</td>
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<td>10μm</td>
</tr>
<tr>
<td>Proximity Sensor–Reed switch, magnetically actuated</td>
<td>3</td>
<td>0.1mm</td>
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<tr>
<td>SubAssembly</td>
<td>Part Name</td>
<td>Quantity</td>
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<tr>
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<tr>
<td>DetentSubAssembly</td>
<td>Detent Stage Wedge</td>
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<tr>
<td></td>
<td>3/4 Angle Brace</td>
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<tr>
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<td>3/4 Angle Brace Bottom</td>
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<td>Pneumatic Pusher Brace</td>
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<td>Festo Compact Cylinder</td>
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<td>ArticulationDetent</td>
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<td>Proximity Sensor SME</td>
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<td>Flexible Rack</td>
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<td>Rack Angle Mount</td>
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<td>Motor Mount</td>
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<td>Angle Encoder</td>
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<td>High Torque SloSyn Motor</td>
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<tr>
<td>Frame</td>
<td>Motor/DetentMount</td>
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<td>Bearing Housing</td>
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<td>Bearing Retainer</td>
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<td>Articulation/Camera Structure</td>
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<td>Front MountBlock</td>
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<td>Bottom Roller Mount Block</td>
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<td>RBC Bearings - Under Roller</td>
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