Lightweight, Low-Power Coarse Star Tracker

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The LIST Concept

- Medium accuracy star tracker for small satellites with coarse pointing requirements

- LIST particularly targeted for micro space or quick launch capability
  - The SHERPA project

- LIST design consistent with low complexity modular bus design

- Optimized for micro space applications
  - Low Weight
  - Small Footprint
  - Minimize Cost
  - Adequate Accuracy for Majority of Applications
Current development in star trackers is focused on increasing accuracy and speed at the expense of other factors:

- Large footprint, mass and cost
- High power requirements
- These complex trackers are not suitable for very small satellite usage

Accuracies under 10 arc seconds

Ball CT-611

Ball CT-601

Caltrac
Market Details

Low Accuracy Sensors

- Lower cost sun and earth limb sensors are not accurate enough for satellites which require moderate ACS accuracy

- Multi-axis tracking requires multiple sensors in unison
  - Leads to increased complexity and the same disadvantages as the high accuracy star trackers
Market Details II

- Between the two types there exists a void
- A market niche exists for a medium accuracy star tracker designed for economical packaging
  - Will be enabling technology for more economical very small satellites with course pointing ACS requirements

![Graph showing accuracy vs. price for different star trackers]
Technology Summary

- Make sacrifices in accuracy and speed to enable better economics
- Utilize latest technologies to optimize for a lower performance goal
- Use simpler optics to minimize weight and complexity

Diagram:
- Pinhole Lens
- 30 Field of View
- Active Pixel CMOS Imager
- Image
- Pattern Recognition Software
- Star Catalog
- Processor
- Roll, Pitch, and Yaw Position (x, y, z)
Performance Sacrifices

- Fewer tracking pairs
  - Maximum of 4 star pairs

- Smaller Star Database
  - Limit to magnitude 4 and brighter
  - \( \approx 600 \) stars in database

- Longer Latency Requirements
  - 1 Hz update rate adequate for most applications

- Pinhole lens optics
Performance Advantages

- Minimizing update rate improves power efficiency and lowers cost

  - Smaller star database means lower processing times
  - Reducing exposure time minimizes power by allowing a lower imaging frame rate
  - Reducing tracked pairs
  - Longer latency
Attainable Performance

- Despite sacrifices in performance, 75-100 arc seconds of accuracy will be attainable.

- This will enable small cost effective vehicles to attain 3 axis pointing accuracies better than .25 degrees.

- This level of performance should be possible in a compact low power package:
  - Under 1 Watt power consumption
  - 300 gram mass projection
  - Less than 10x10x5 CM footprint
  - Size and weight comparable to best sun sensors
Algorithm Requirements

- Maintaining Accuracy
  - Accuracy maintained through multiple star tracking

- Attaining Minimum Roll Rate Goal
  - Selection of exposure time critical
  - Performance of CMOS imager must be considered to calculate roll
Roll Rate Limitations

- Substantial spacecraft roll can be tolerated
- Limiting factor is the imager update rate
  - As spacecraft roll increases, stars turn into blobs or streaks of reduced intensity.
  - “Streaked” stars reduce accuracy
- 3 degrees/second attainable with 30 degree FOV using OTS imaging chip

![Graph showing roll rate limitations and limiting magnitude](image-url)
Ground Testing Concept

- Algorithm concept tested with Matlab simulation on images taken from ground
- 330K pixel image, with 1400 star database
- Processing was found to take 3.7 million floating point operations
  - Well within processing power of baseline processor
Further Possible Optimization

- More Efficient Grid Algorithm
- Minimize Star Catalog
  - Catalog size directly determines processing power required to attain match
- Reduce Update Rate
  - Halving update rate to 0.5 Hz could potentially significantly reduce power requirements further
- Implement Tracking Mode
  - Could lower processing load, but also increase software complexity
Conclusion

- A star tracker designed specifically for very small satellite requirements, yields a unique product with a large potential market.

- Minimizing cost, space, mass, and power consumption in star trackers will enable many more very small satellite missions.