AFFORDABLE CRYOCOOLERS FOR COMMERCIAL INFRARED IMAGING

A Veprik, S Zehctzer, A Daniels, R Refaeli and A Wise
CRYOTECH LTD, GEVASOL GROUP, Israel
OUTLINE

- INTRODUCTION
- A LITTLE BIT OF HISTORY (May 2018-Oct 2020)
- PRESENT STATUS (Dec 2020)
- DESIGN FREEZE – V.4
- VIBRATION ISSUES
- WAY FORWARD
INTRODUCTION

- Cryogenically cooled vs uncooled IR detectors
  - Longer detectability distances
  - Better temperature and spatial resolution
  - Ability to detect/observe/track fast moving objects
  - Less demanding optics

- Military graded mechanical cryocoolers
  - Low quantities
  - High ownership cost (buying, complicated IDDCA integration and replacement)
  - Tough export regulations

- Emerging commercial marketplace calls for affordable cooled IR imaging
  - High quantities
  - Uncompromised cost, SWaP, life span, ease of integration, vibration export
  - Relaxed export regulations - “specially designed” concept
TYPICAL MILITARY GRADED SPLIT STIRLING CRYOCOOLERS

- Dual – piston compressor
- Side-by-side packaging
- Pneumatic expander - short cold finger & massive warm side

Thales UP8197 (a), L3 L200 (b), DRS microIDCA (c), Ricor K588 (d), FLIR FL-100 (e), Cobham LC1076 (f), AIM MCC025 (g).
COST REDUCTION

- Price goal: $XXX at 10,000/ann factory aggregate

- Design to cost:
  - KISS – “Keep it simple, stupid!”
  - Single-piston compressor
  - Relaxed mechanical tolerances
  - Cost effective materials
  - Mass production methods for parts manufacturing, assembling, inspection and testing
  - Cost effective purge/fill, sealing and characterization procedures
# A LITTLE BIT OF HISTORY

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Planned</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kick off</td>
<td>May 2018</td>
<td>May 2018</td>
</tr>
<tr>
<td>R&amp;D lab establishment, staffing</td>
<td>Jan 2019</td>
<td>Feb 2019</td>
</tr>
<tr>
<td>Prototypes design, manufacturing, assembly and “first ice” observation</td>
<td>Aug 2019</td>
<td>Aug 2019</td>
</tr>
<tr>
<td>Optimization for “open air” minimum temperature, mechanical stability issues</td>
<td>Nov 2019</td>
<td>Dec 2019</td>
</tr>
<tr>
<td>Redesign towards integration with simulation Dewar (split only)</td>
<td>Jan 2020</td>
<td>Jan 2020</td>
</tr>
<tr>
<td>Integration with simulation Dewar</td>
<td>May 2020</td>
<td>Aug 2020</td>
</tr>
<tr>
<td>Characterization and optimization</td>
<td>Sep 2020</td>
<td>Nov 2020</td>
</tr>
<tr>
<td>Design freeze</td>
<td>Dec 2020</td>
<td></td>
</tr>
</tbody>
</table>
INTEGRAL DESIGN V.1

Pros:
- Compactness
- Robustness
- Less weight
- Less power consumption
- Zero vibration moments

Cons:
- Enlarged optical size
- Less packaging flexibility

200 gr
SPLIT DESIGN V.1

200 gr (compressor) + 30gr (cold head) with monolithic Ti cold finger

Pro:
- Packaging flexibility
FIRST FROST— AUG 2019
INTEGRAL COOLER V.2
SPLIT V.2 PERFORMANCE IN VACUUM
PRESENT STATUS

V.3 SPLIT
V.3 SPLIT

Weight: 140gr with cold finger
V.3 SPLIT

- 1000 hours full power burn-in testing
V.3 SPLIT

Simulation Dewar 200mW@150K@23C

- No cold shield
- Cold finger not polished
- L=21mm; WT=150um

Simulation Dewar heat load evaluation

- Vendor simulation tool
- Warm-up calorimetry

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CF conductivity</td>
<td>122.6 mW</td>
</tr>
<tr>
<td>CF radiation (e=0.5)</td>
<td>45 mW</td>
</tr>
<tr>
<td>Substrate radiation</td>
<td>31 mW</td>
</tr>
<tr>
<td>Total</td>
<td>199 mW</td>
</tr>
</tbody>
</table>
EVALUATION TEST BENCH
Time to image (290 K to 160K) – 115s
150K TEMPERATURE CONTROL MODE
TEMPERATURE CONTROL MODE
120 K TO 200K

Dewar heat load 200mW@150K@23C

<table>
<thead>
<tr>
<th>Temperature, K</th>
<th>120</th>
<th>130</th>
<th>140</th>
<th>150</th>
<th>160</th>
<th>170</th>
<th>180</th>
<th>190</th>
<th>200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conductivity, mW</td>
<td>146</td>
<td>138</td>
<td>130</td>
<td>122</td>
<td>114</td>
<td>106</td>
<td>98</td>
<td>89</td>
<td>81</td>
</tr>
<tr>
<td>Radiation, mW</td>
<td>79</td>
<td>78</td>
<td>77</td>
<td>76</td>
<td>75</td>
<td>73</td>
<td>71</td>
<td>68</td>
<td>65</td>
</tr>
<tr>
<td>Dewar heat load, mW</td>
<td>225</td>
<td>216</td>
<td>207</td>
<td>198</td>
<td>188</td>
<td>178</td>
<td>168</td>
<td>157</td>
<td>146</td>
</tr>
</tbody>
</table>
MODIFICATIONS PRIOR TO CONFIGURATION FREEZE – V.4

- Cold finger WT -120um
- Cold finger length (active) - 27mm
- Cold finger OD polish
- Warm side of cold head – less void volume
- Actuator redesign

Weight: 120 gr excl. cold finger
Vibration issues – tuned dynamic counterbalancer (optional)

1. proof ring
2. planar flexural bearing
3. screws
4. threaded ring
5, 6. spacers

Added weight 55 gr
Vibration issues

Dynamic design
Vibration issues

Platform weight 2kg

![Graph showing acceleration vs frequency with and without counterbalancer.](image)

- With no counterbalancer
- With counterbalancer

Platform weight 2kg
WAY FORWARD

- Extended R&D lab inc. clean room, staffing – Apr 2021
- Manufacturing facility, staffing – Nov 2021
- Testing facility – life testing, environmental extremes – Dec 2021
- Evaluation units availability – Aug 2021