Australian Government
Department of Industry

AST3-NIR DETECTOR TRADE-OFF

REVISION 0.3

Rev. No.	Author	Approved for Issue		
		Name	Signature	Date
1	J. Lawrence	J. Mould		

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Figure 1. Detector procurement timeline PAGEREF _Toc450114007 \h 7

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1 INTRODUCTION

This document describes the trade-off between the two options for detector procurement for the AST3-NIR project, infrared detector arrays provided by: Teledyne or Selex ES.

2 COST COMPARISON

The original project budget prepared in mid-2014 included a 2kx2k H2RG Science Grade (SG) chip from Teledyne. This chip has been fixed in USD price for over 5 years. The detector was de-scoped to a H2RG Engineering Grade A (EG-A) chip in 2015 to account for the increase in the USD with respect to the AUD. The EG-A model is a 2kx2k chip with at least a 1kx1k contiguous region conforming to the SG specifications. With the recent addition of the Swinburne contribution to the budget of $175k, the total available for detector procurement is now $525k. This allows the detector to the re-scoped back to the SG device for the Teledyne option.

The Selex option has been explored since project commencement due to potential issues with export of the Teledyne chip. Selex ES indicated initially (in Sept 2015) an approximate cost in the range of 125-250k GBP for a single 1.3kx1k chip and 250k GBP for a mosaic of 2 of these chips. After development of a detailed specification and interface document including requirements for design and supply of custom electronics, Selex ES provided a cost (in Jan 2016) of 430k GBP for a 2 chip mosaic with no reduction in cost for purchase of 1 chip. Since then, Selex have provided an estimate for providing two off detectors with standard electronics, controller, preamp and cables of 335k GBP, reduced to 310k GBP for one off.

See Table 2-1 for summary of costing information, and Table 2-2 for summary of options. For further consideration we consider only Option 1a and 2a noting that the latter will require at least an additional $100k to be sourced.

Table 2- Costing

	Option	**OS cost**	**Exchang e**	**AUD**
Original budget	Teledyne H2RG SG	350k USD	1	350k
SUT contribution				175k
Total available				**525k**

Table 2- Options

	Option	**OS cost**	**Exchang e**	**AUD**
Option 1a	*Teledyne H2RG SG*	*350k USD*	*1.4*	*490k*
Option 1b	Teledyne H2RG EG-A	250k USD	1.4	350k
Option 2a	*Selex 1 x 1276 x 1024 standard*	*310k GBP*	*2.0*	*620k*
Option 2b	Selex 2 x 1276 x 1024 standard	335k GBP	2.0	670k
Option 2c	Selex 2 x 1276 x 1024 custom	430k GBP	2.0	860k

3 Technical Comparison

3.1 Deliverables

3.1.1 Teledyne

The Teledyne option is based around the Hawaii 2RG device and integrated cryogenic controller. This US company are the world leading manufacturers of high-end low-noise infrared arrays, and have supplied these devices to many astronomical instruments over the last several decades. All deliverable elements are standard parts from Teledyne:

- H2RG SG HgCdTe 2048x2048 pixel array;
- SIDECAR ASIC in a 337-pin LGA Ceramic Package;
- Cyrogenic PCB assembly;
- 15” Flex cable w/ Hirose Connectors;
- JADE-2 card (or SAM module – TBC-Teledyne);
- Mini USB cable;
- CD with SIDECAR ASIC Operating Software;
- Installation, Maintenance, and Operations Manual;

3.1.2 Selex ES

The Selex ES option is based around a new array that was developed in 2014/15 by Selex under an ESA contract. This UK-based company has been successful in developing smaller pixel count avalanche HgCdTe devices used in several space missions over the last decade. They are looking to expand their market with larger pixel count non-avalanche devices, and see themselves as a potential competitor to Teledyne. Selex ES would subcontract the controller, testing, and software aspects of the project to UKATC. The deliverables from Selex are:

- 1 x HgCdTe 1276 x 1024 pixel array with ROIC multiplexer that is a clone of the ESA device mounted on a standard test-card;
- Astronomical Research Cameras (ARC) Leach Controller (electronics and housing);
- Standard interconnects used in their test Dewar (cables, connectors including vacuum, and circuits between the array and the controller including pre-amplifier);
- UCam Operating software from UKATC;
- Operational and maintenance manual.

The preference was for a custom array PCB, and custom interconnects to account for mounting the chip and instrument filter to the cryostat cold head, to provide mounting flanges for the preamplifier, and to ensure appropriate rating for all connectors and feedthroughs. This has been discounted due to cost (as described above). The lower cost option uses standard electronics, preamp, and cables that have been developed at Selex (and UKATC) for testing purposes. The technical implications of this choice are unclear. It is likely that minor modification will be allowed though costing for this is yet to be negotiated.

3.2 Performance Requirements

Performance requirements for the two chips are given in Table 3-. The largest impact is pixel count. The camera optical design will be modified to account for the difference in pixel size. Risk for the red edge should be noted. Other differences are considered to have minor impact on the project.

Table 3- Performance Requirements

Requirement	**Teledyne – option 1a**	**Selex ES – option 2a**
Number pixels	2048 x 2048	1276 x 1024
Pixel size	18 μm	15 μm
QE blue edge (2.24 μm)	> 0.80	> 0.80
QE band centre (2.36 μm)	> 0.80	> 0.80
QE red edge (2.50 μm)	> 0.5 (1)	> 0.50
Dark current	< 1 e-/pix/sec (2)	<1 e-/pix/sec
Read noise (CDS)	< 18 e-rms	< 25 e-rms
Read noise (Fowler)	< 3 e-rms	< 5 e-rms
Array read time	< 4 seconds	< 4 seconds
Persistence	< 3 e- after 2 mins	< 5 e- after 2 mins
Pixel operability	>99.5 %	>99.5 %
Inoperable clustering	< 50 pixels	< 30 pixels
Full well	>80,000 e-	>80,000 e-
Crosstalk (optical and electrical)	<2%	<2%
Linearity	<1%	<2%
Peak power consumption	TBD	<100W
Average power consumption	TBD	<80W

Table Notes:

(1) This extends beyond the standard red-end cut-off, but is within typical deviation for a batch of chips. There is a risk that a high red-end cut-off device is not available.

(2) This is driven by the requirement for the instrument rather than the capability of the Teledyne device, which can deliver substantially lower dark current.

4 PROCUREMENT, EXPORT, AND TIMELINE

4.1 Teledyne

The Teledyne H2RG detector and the ASIC SIDECAR controller (both items locations inside the camera cryostat) are listed as restricted items on the US munitions list. Export from the US is thus controlled via ITAR. An export license is required to be approved by the US State Department. The time to approval is uncertain and depends on the complexity and sensitivity of the application, though is likely to be in range 3-12 months.

Ordinarily applications for export of ITAR goods to countries on the list of US Embargoed and Sanctioned countries, which includes China, are denied – though exceptions can be made.

The ITAR list was reviewed in 2015 and under a proposed new category infrared focal plane arrays that are encapsulated in a camera format may be moved from the ITAR list to the EAR. EAR items are regulated by the US Commerce Department and are generally less restricted for export, though a license is still required. It is yet to be determined whether this category applies.

Initial advice from Teledyne was that only informal communications from the US State Department were possible prior to the license application. Such informal discussions were held in April 2015, with neutral outcomes. The new export control manager for Teledyne has recently indicated (April 2016) that it is possible to get advice from the State Department on the likelihood of success for an export licence application and on recommendations for modifying the application so that it has a better chance of approval. This can be achieved through a formal advisory opinion letter.

Teledyne will draft the advisory opinion letter and intend to submit in mid-May. It usually takes 30-60 days to get response from such a letter. If a positive response is obtained, then the next step would be to sign a contract for the procurement.

Regarding contract termination (i.e. if licence application is denied), Teledyne have agreed that there would be no payment required. Usually all payments are made after deliver of the array.

Teledyne have recently begun the process to fabricate 3 lots of IR arrays (2 x shortwave and 1 longwave). The yield is expected to be ~16 FPAs (science grade). These would be ready for delivery in the first half of 2017. This timeframe fits with a 12 month licence application.

If we proceed with Teledyne there is a small chance the arrays would be delivered in time for the 2018 shipping. However, there is significant risk that the procurement is delayed or there is not enough time to properly integrate the chip with the instrument and telescope.

4.2 Selex ES

The Selex ES chip is classed in the UK a dual-use device. This does require an export license to remove from the UK, but is not as strict as the US controls. The license application would occur after the contract is in place, with a typical turn-around time of 20 days. Selex would put the order on hold until the approval was obtained. The contract would need clauses in place that deal with rejected license – even though this unlikely. The payment structure and timing is yet to be negotiated.

Precedence exists for export of these chips by Selex to an end-user in China (for a geology experiment).

The typical lead time for the Selex array is 4-9 months, but our order would be more complicated than usual as requires custom packaging and controller. Selex have suggested 9-12 months is appropriate. Prior to finalising the contract a period of negotiation and specification development is required to account for desired minor modification. This is expected to take several months.

4.3 Australian Export Control

Export of goods outside of Australia is now governed by a new Export Control Act that came into effect in April 2016. Under this act any goods that are listed on the Defence and Strategic Goods List require a permit for export unless an exemption applies.

Infrared detector arrays appear under the Sensitive List of Part 2: Dual Use List of the DSGL. There is a general exemption for 'basic scientific research' that may apply in this case. This needs to be clarified with the Australian government Department of Defence.

4.4 Timeline

Timeline for detector procurement is shown in Figure 1. This illustrates decision points and implications to schedule. If we proceed with Teledyne: shortest possible lead time gives delivery in 9 months, longest lead-time for Teledyne chip delivery is 17 months, best outcome for Selex chip delivery is 14 months, and longest lead-time for Selex chip delivery is 28 months. If we proceed with Selex, shortest possible lead-time is delivery in 13 months, longest is 16 months.

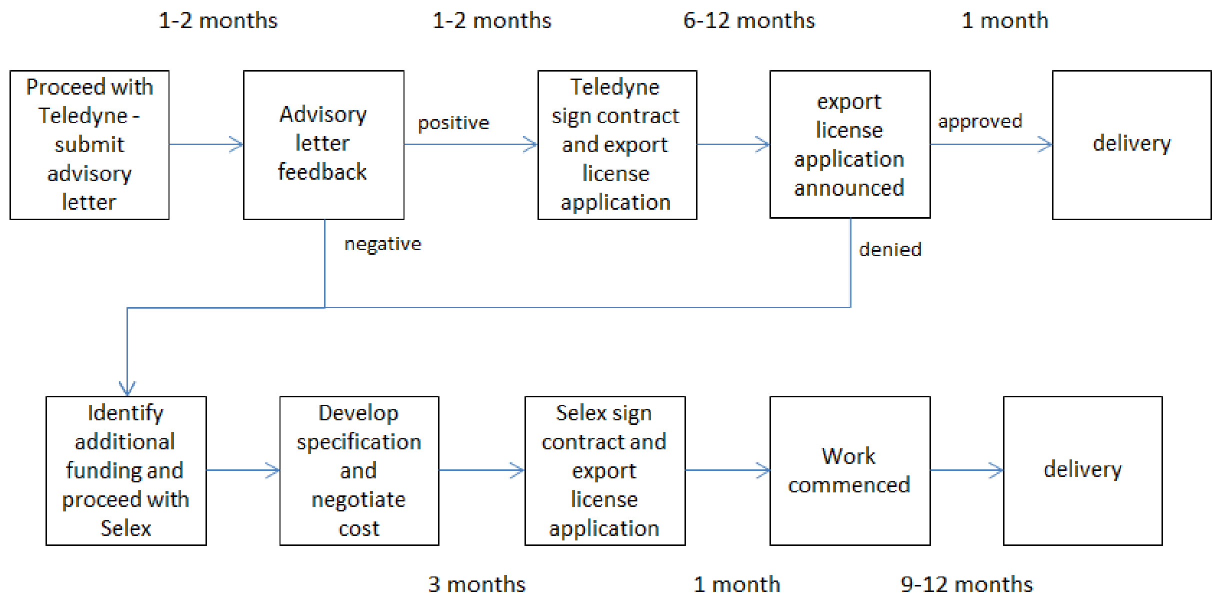

Figure . Detector procurement timeline

5 Risks and Recommendation

5.1 Risk

Risks are considered in four categories:

- **Performance**: there is a potential risk to sensitivity with the Teledyne chip if we are allocated a red-end cut-off shorter than preferred, although this is more than compensated by the increase in pixel count (factor 3.2) leading to increase in surveyed sky coverage;

- **Technical**: the lowest risk option is the Teledyne chip as this is the most well developed product with clearly defined interfaces;
- **Financial**: For the Teledyne product the cost is well understood but there is risk that if the export license is denied, substantial rework on the instrument design is required leading to higher labour costs;
- **Schedule**: Selex is clearly the lowest risk option from a schedule point of view.

5.2 Recommendation

Of the two options, the Teledyne HR2G chip is preferable for our project to the Selex chips. We should go through the flow chart as shown in Section 4.4, starting with Option 1a, and if Option 1a fails, continuing with Option 2a.

6 DRAFT VERSION HISTORY

Version	Date	Author	Comments
0.1	04/05/2016	JL	Draft
0.2	5/5/2016	JT	Revision
0.3	24/5/16	LW	5.2