Flex Pivot Options

SPIRE BSM Discussion document - Ian Pain. 22.Aug.01

The Baseline flex pivot choice identified at DDR is technically acceptable but costs exceed the original budget estimate.

From Lucas TRW the baseline price for 18 pivots x two types, the total order cost would be ~£94.5k Adding in minimum spares (for a total buy of 20 of each type) would bring the total to £97k. This represents an over-run of £84k on the £13k budgeted for flex pivots. Because of other savings in the BSM programme, the available budget for flex pivots is however, now £30k. i.e Costs above £30k will require savings elsewhere to stay within total cost.

Note that there is a complication between ability to run at higher power dissipation and motor choice. If MPIA/PACS/Zeiss select a Copper winding rather than the originally baselined Aluminium, the increase in dissipation is significant (about a factor of 5). Based on discussions with MPIA and UK motor winders, we should consider Copper the baseline until confirmed by Zeiss (late-mid'02). Thus motor availability constrains flex pivot choice.

Description of Options

Greyed out areas are not favoured/possible. Notes referenced in roman numerals.

Flex Pivot Option	Description	Cost	Power - Aluminium coil	Power - Copper coil	Comments
1. Budget	Original assumption.	£13k	4mW		Assumption of £13k was optimistic.
2. Baseline	Inconel flex pivots. Two types (chop and jiggle).	£97k (*)	1.3mW (iv)	3.2mW (iii)	Based on Lucas TRW quote (ii). VAT & import duty not included - waiver would be required
3. Joint procurement of baseline design	As 2, but joint procurement with another agency such as SRON,	£53-63k	1.3mW (iv)	3.2mW (iii)	Unlikely £17-22k saving per pivot type by sharing tooling and material price pro-rata. But SRON only interested in jiggle type: maybe ask LAM to procure back-ups too? (unlikely)
4. 304 stainless	As 2, but use austenitic stainless steel.	£91.7k	1.3mW (iv)	3.2mW (iii)	Saves £1.4k per type of flex pivot. Possible better fatigue life but reduced strength (TBC). Not favoured, as if having specials made may as well get the best.
5. 429 stainless	Uses off the shelf pivots but need to upscreen, and schedule extra vibration tests	£34.2k	1.3mW (iv)	3.2mW (iii)	risk of failure on cold vibration Assume upscreen by buying 4 x requirements (20 pivots x 3 @ £70) and doing 2 x extra warm vibration tests (@£2k); 2 x extra cold vibration tests (@£10k/test) with 20 extra days work (@£300/day).
6. Material brokerage	As 2 but assume we Could sell material to a third party broker, the	£68.9k	1.3mW (iv)	3.2mW (iii)	Unlikely £12.8k saving per pivot type. Sell on of material may not work (or run into tax and duty issues)

Flex Pivot Option	**Description**	**Cost**	**Power - Aluminium coil**	**Power - Copper coil**	**Comments**
	original supplier or e.g. RAL				
7. ESA procurement?	Ask ESA procure the pivots for us	Nominal £13k	1.3mW (iv)	3.2mW (iii)	Assumed impossible would be ideal if we could do it.
8. Common Jiggle Pivot	switch to a single pivot type, 7010-600	£58.8k	11.8mW (v)	55mW (v)	Cannot use this as baseline as requires Al. Windings Saves £35.7k on material & tooling. Risetime may be compromised if motor saturates
9. Common Chop Pivot	switch to a single pivot type, 7010-800	£73.8k	1.0mW (vi)	1.7mW (vi)	Requires major lightweight of jiggle frame or waiver on load (by >65%) Saves £35k less say £20k for re-engineering & increased manufacture costs
10. Hybrid soultion	Procure Inconel Jiggle pivot in common with SRON 7010-600. But use a stainless steel pivot for chop axis.	£41.5k	1.1mW (ix)	2.0mW (ix)	Risk of problems with stainless steel chop pivot. Late stage de-scope to option 11 Saves £17k on shared material for inconel pivot. Cost of stainless is half of option 5.
11. Baseline chop, shared procurement on jiggle	Procure Inconel Jiggle pivot in common with SRON 7010-600. Buy our own inconel chop pivot	£75-80k	1.1mW (ix)	2.0mW (ix)	Requires 85% lightweight of jiggle frame Saves £17-22k on shared material
12. Common intermediate pivot	intermediate stiffness pivot to BSM specification compromise between the two. (eg Use SRON 7010-600 as example)	£72.8k	3.6mW (vii)	14.5mW (vii)	Would make any light-weighting or power budget problems a trade-off. The 7010-600 needs a lightweighting of the jiggle frame of 85% (possible). Saves $35k less £10k for engineering costs. Risetime may be compromised if motor saturates
13. BE Systems Pivot. 0.15mm blade	identical to SMEC pivots or a slightly lighter flexure	£55k	1.4mW (viii)	3.9mW (viii)	Cost approx. £1k per pivot x 40 . As unit is 2mm bigger, need to re-engineer chop & jiggle stage, motor mounts and BSMs (say £15k including redesign & new prototype m/c).
14. Spark Eroded Pivot	Special pivot, maybe developed by Zeiss	?		?	Cost as option 13, plus 'Zeiss' factor

Flex Pivot Option	Description	Cost	Power - Aluminium coil	Power - Copper coil	Comments
15. Smiths Industries Pivots	Maraging Steel Pivot per Smiths Industries	?	~4mW	~2mW	Would be a aerospace rated part. Cost and power budget assumed same as 11. Maraging should be OK cold (but is SCC 'C' rated)

Comparison of favoured options

Ideal cost target is £30k.

Flex Pivot Option	Description	Cost	Power - Aluminium coil	Power - Copper coil	Risks
2. Baseline	Inconel flex pivots. Two types (chop and jiggle).	£97k (*)	1.3mW	3.2mW	• VAT & import duty
11. Baseline chop, shared procurement on jiggle	Procure Inconel Jiggle pivot in common with SRON 7010-600. Buy our own inconel chop pivot	£75-80k	1.1mW	2.0mW	• Requires 85% lightweight of jiggle frame • Saves £17-22k on shared material
10. Hybrid soultion	Procure Inconel Jiggle pivot in common with SRON 7010-600. But use a stainless steel pivot for chop axis.	£41-48k	1.1mW	2.0mW	• Risk of failure of stainless steel chop pivot. • Needs 85% lightweight of jiggle frame • Late stage de-scope to option 12
13. BE Systems Pivot. 0.15mm blade	identical to SMEC pivots	£55k	1.4mW	3.9mW	• delay to re-engineer (1-2 months) • mass growth • BE systems QA • Not flown before • No margin on power

5. 429 stainless	Uses off the shelf pivots but need to upscreen, and schedule extra vibration tests	£34.2k (+80k for cold vibration?)	1.3mW	3.2mW	• risk of failure on cold vibration
					• if need to re-qualify.
					  • 3-6 months late
					  • Need extra £97k to buy inconel if fails
					  • Need £50k? for catch-up costs
					• Assumes 2 extra cold vibrations @£10k (real cost £50k TBC??)

11. Common intermediate	intermediate stiffness pivot	£72.8k	3.6mW	14.5mW	• Needs 85% lightweighting of the jiggle frame (possible)

Flex Pivot Option	Description	Cost	Power - Aluminium coil	Power - Copper coil	Risks
2. Baseline	Inconel flex pivots. Two types (chop and jiggle).	£97k (*)	1.3mW	3.2mW	• VAT & import duty
11. Baseline chop, shared procurement on jiggle	Procure Inconel Jiggle pivot in common with SRON 7010-600. Buy our own inconel chop pivot	£75-80k	1.1mW	2.0mW	• Requires 85% lightweight of jiggle frame • Saves £17-22k on shared material
pivot	to BSM specification compromise between the two. (eg Use SRON 7010-600 as example)				• Copper motor coils don't meet spec

Notes

Costs:

i. all costs based on $1.40:£1.00, and 10.00FF:£1.00

ii. The Lucas flex pivots includes $28k of minimum material quantity charges and $22k of tooling charges, per type of pivot (we have two types, hence $100k). We get 18 of each type but buy enough material for 50. Assuming an exchange of 1.4 and that we do NOT pay import of VAT, this translates as ~£71k, for material and a unit cost of approx £640 per pivot

Power budget calcs:

iii. baseline pivot, copper coil:

0.80mW sensor
0.84mW chop (2.4degrees, 2 Hz, 47 Nmm/rad. stiffness)
1.54mW jiggle (0.6 degrees, 0.5Hz, 367 Nmm/rad stiffness)
total: 3.2 mW

iv. baseline pivot, aluminium coils

0.80mW sensor
0.17mW chop (2.4degrees, 2 Hz, 47 Nmm/rad. stiffness)
0.31mW jiggle (0.6 degrees, 0.5Hz, 367 Nmm/rad stiffness)
total: 1.28 mW

v. using a baseline jiggle pivot in the chop and jiggle axis:

chop stiffness goes up by 7.94x. Chop power goes up by 63x. thus total power = 55mW (Cu); 11.8mW (Al),

vi. using a baseline chop pivot in the chop and jiggle axis:

jiggle stiffness goes down by 7.94x. Jiggle power goes down by 63x. thus total power = 1.7mW (Cu); 1.0mW (Al),

vii. Common intermediate SRON 7010-600 (187Nmm/rad) as example

chop stiffness goes up by 3.98x. Chop power goes up by 15.8x.
jiggle stiffness goes down by 1.96x. Jiggle power goes down by 3.85x.

thus total power = 14.5mW (Cu); 3.6mW (Al),

viii. BE systems 0.15mm

0.15mm flexure for jiggle & chop
Stiffness: 89.1Nmm/Rad (dominique's note)

- jiggle stiffness down by 4.11x, power down by 16.89x
- chop stiffness up by 1.90x, power up by 3.6x

thus total power: 3.9mW (Cu) ; 1.4mW (Al)

ix. Hybrid solution

SRON 7010-600 pivot for jiggle. jiggle stiffness goes down by 1.96x. Jiggle power goes down by 3.85x.
Baseline 5010-800 for chop.

Power: 2.0mW (Cu); 1.05mW (Al)