Decision Process: Presentation to the STDT for the X-Ray Surveyor

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Decision Process: Why, What, and How

- **Why** have a decision process?
- A structured rational decision process is useful when
  - A decision has to be made
  - The stakes are high
  - The decision needs to stick (consensus is important, vs vote or decree)
  - Timeliness, transparency, communication, etc are also important

- I can show you a process that can work for you
  - Has worked well in similar situations
  - Will show examples

Decision Process

- Decision Process is a bit like a recipe:
  - it has a "best format" (ingredients) - the “what”
  - "best practices" (steps to follow) - the “how”
- In this case, it's ~1 part Excel matrix (“what”) and ~3 parts best practices (“how” you do it)

- Like any recipe one can improvise, within some limits

THE WHAT

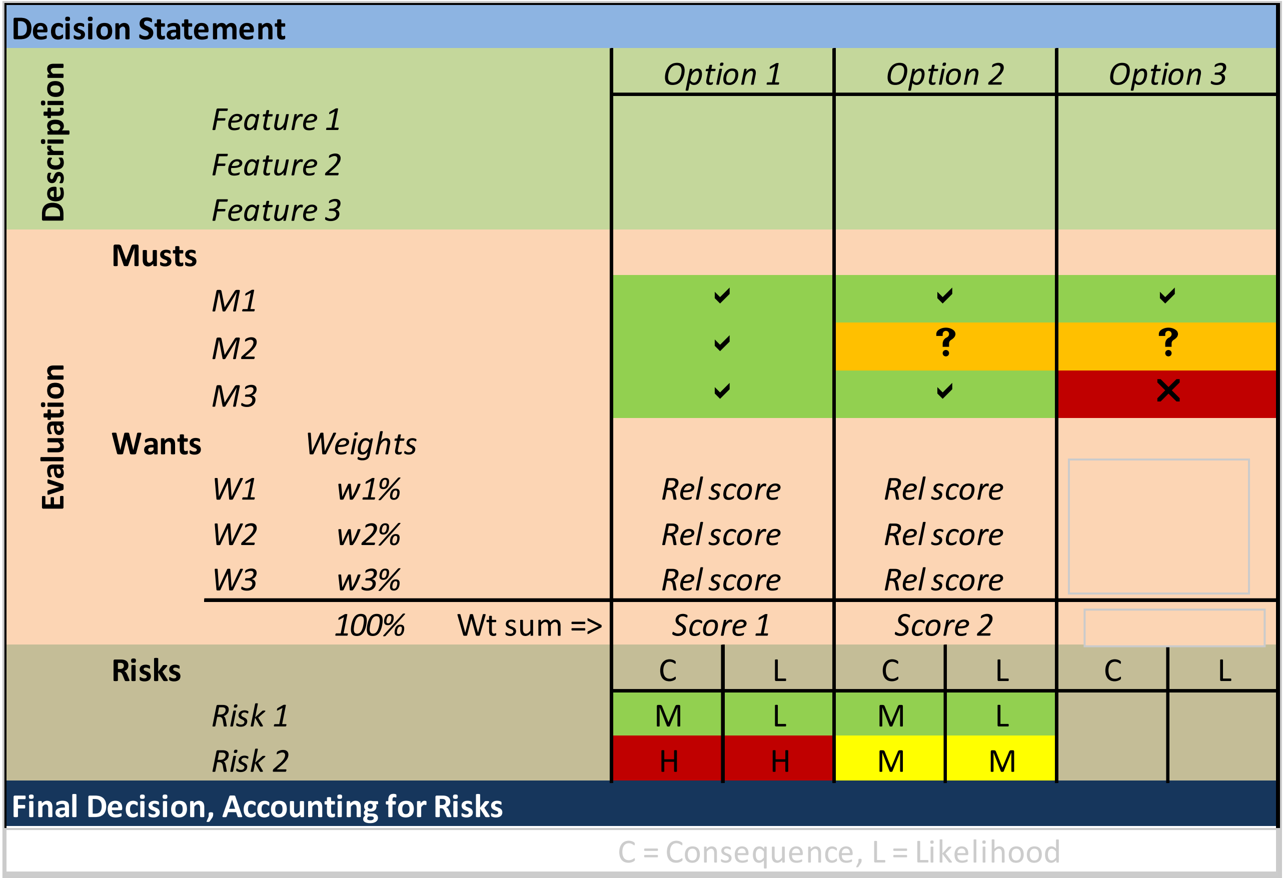
Best Format

Best format is the Kepner-Tregoe method for rational decision making

- Fundamentally one page, allows creativity, transparency, communication, consensus
- Around since the 1950's, see *The Rationale Manager*
- I learned at UCLA Extension 3-day course
  (still taught, July 2016 class)

Context for Recommendation Approach

- Adapted from Kepner-Tregoe methods. The Rational Manager, Kepner and Tregoe, 1965
- A systematic approach for decision making.



Decision Statement										
Description					*Option 1*		*Option 2*		*Option 3*	
		Feature 1								
		Feature 2								
		Feature 3								
Evaluation	**Musts**									
		M1			✓		✓		✓	
		M2			✓		?		?	
		M3			✓		✓		✕	
	Wants		*Weights*							
		W1	*w1%*		*Rel score*		*Rel score*			
		W2	*w2%*		*Rel score*		*Rel score*			
		W3	*w3%*		*Rel score*		*Rel score*			
			100%	Wt sum =>	*Score 1*		*Score 2*			
	Risks				C	L	C	L	C	L
		Risk 1			M	L	M	L		
		Risk 2			H	H	M	M		
Final Decision, Accounting for Risks										

C = Consequence, L = Likelihood

Musts and Wants

- Typically categorize into

  Science (e.g. beyond state of the ground at launch)

  Technical (e.g.TRL5 by KDP-B, and TRL6 by PDR)

  Schedule (e.g. launch by TBD date)

  Cost (e.g. likely target cost)
- Musts relate to threshold, Wants can include “reflected Musts” (ie, go beyond the Must). Examples from exoplanets:
  - Must: characterize at least one Hab-zone Earth
  - Want: maximize # characterizations (beyond 1)
- Musts are go/no_go, Wants are relative and weighted
- Risks/Opportunities are handled, but separately, as in, would the answer change if this risk (or opportunity) came true?
  - Example: would architecture change if eta_earth were 1.0 vs 0.1?

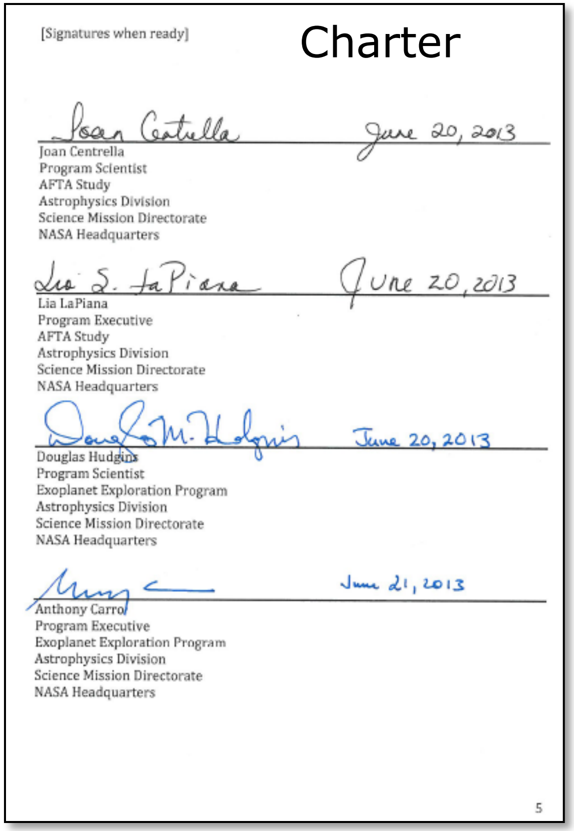
A Recent Examples

- AFTA Coronagraph Working Group
  - Final presentation: follow link at bottom this page
    - http://exep.jpl.nasa.gov/presentations/

    http://wfirst.gsfc.nasa.gov/science/AFTA_Coronagraph_Arch_Selection/Coronagraph_Downselect_Rec_Dec13_2013.pdf

ACWG Membership

- These represent Program, Study Office, SDT, and Community:



Charter

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5

Workshop Organizers:

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- Additional consultants participate at request of Steering Group; names listed in backup charts

Trade Criteria:
Defining a Successful Outcome

DECISION STATEMENT: Recommend a primary and backup coronagraph architecture (option) to focus design and technology investments

MUSTS (Requirements): ***Go/No_Go***

1. Science: Does the proposed architecture meet the threshold science drivers?
2. Interfaces: For the threshold science, does the architecture meet telescope and spacecraft requirements of the observatory as specified by the AFTA project (DCIL[1])
3. Technology Readiness Level (TRL) Gates: For threshold science, is there a credible plan to be at TRL5 at start of FY17 and at TRL6 at start of FY19 within available resources?
4. Is the option ready in time for this selection process?
5. Is the architecture applicable to future earth-characterization missions (no showstoppers)?

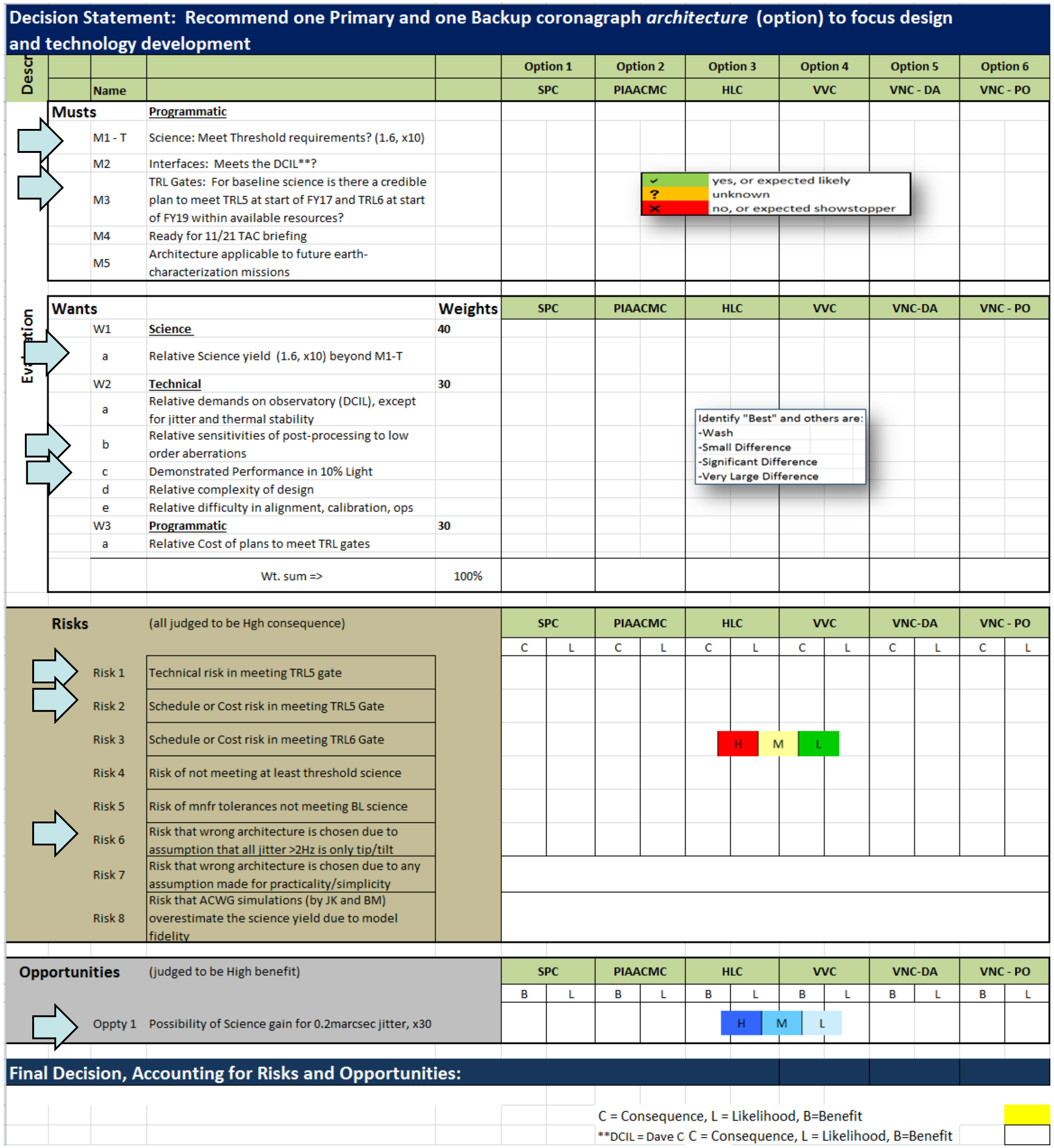
WANTS (Goals): ***Relative to each other, for those that pass the Musts:***

1. Science: Relative strength of science beyond the threshold
2. Technical: Relative technical criteria
   - See details
3. Programmatic: Relative cost of plan to meet TRL Gates

RISKS and OPPORTUNITIES – scored as H,M,L

[1] DCIL = Dave Content Interface List

Evaluation Criteria:
Defining a Successful Outcome for AFTA



Decision Statement: Recommend one Primary and one Backup coronagraph *architecture* (option) to focus design and technology development

Descr	Name			Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
				SPC	PIAACMC	HLC	VVC	VNC - DA	VNC - PO
Musts		**Programmatic**							
	M1 - T	Science: Meet Threshold requirements? (1.6, x10)							
	M2	Interfaces: Meets the DCIL**?							
	M3	TRL Gates: For baseline science is there a credible plan to meet TRL5 at start of FY17 and TRL6 at start of FY19 within available resources?							
	M4	Ready for 11/21 TAC briefing							
	M5	Architecture applicable to future earth-characterization missions							

✓ yes, or expected likely
? unknown
✕ no, or expected showstopper

Wants			**Weights**	SPC	PIAACMC	HLC	VVC	VNC-DA	VNC - PO
	W1	**Science**	**40**						
	a	Relative Science yield (1.6, x10) beyond M1-T							
	W2	**Technical**	**30**						
	a	Relative demands on observatory (DCIL), except for jitter and thermal stability							
	b	Relative sensitivities of post-processing to low order aberrations							
	c	Demonstrated Performance in 10% Light							
	d	Relative complexity of design							
	e	Relative difficulty in alignment, calibration, ops							
	W3	**Programmatic**	**30**						
	a	Relative Cost of plans to meet TRL gates							
		Wt. sum =>	100%						

Identify "Best" and others are:
-Wash
-Small Difference
-Significant Difference
-Very Large Difference

Risks		(all judged to be Hgh consequence)	SPC		PIAACMC		HLC		VVC		VNC-DA		VNC - PO	
			C	L	C	L	C	L	C	L	C	L	C	L
	Risk 1	Technical risk in meeting TRL5 gate												
	Risk 2	Schedule or Cost risk in meeting TRL5 Gate												
	Risk 3	Schedule or Cost risk in meeting TRL6 Gate												
	Risk 4	Risk of not meeting at least threshold science												
	Risk 5	Risk of mnfr tolerances not meeting BL science												
	Risk 6	Risk that wrong architecture is chosen due to assumption that all jitter >2Hz is only tip/tilt												
	Risk 7	Risk that wrong architecture is chosen due to any assumption made for practicality/simplicity												
	Risk 8	Risk that ACWG simulations (by JK and BM) overestimate the science yield due to model fidelity												

H M L

Opportunities		(judged to be High benefit)	SPC		PIAACMC		HLC		VVC		VNC-DA		VNC - PO	
			B	L	B	L	B	L	B	L	B	L	B	L
	Oppty 1	Possibility of Science gain for 0.2marcsec jitter, x30												

H M L

Final Decision, Accounting for Risks and Opportunities:

C = Consequence, L = Likelihood, B=Benefit

**DCIL = Dave C C = Consequence, L = Likelihood, B=Benefit

Indicates Sig. Discriminator

Science Threshold

Science Beyond Threshold

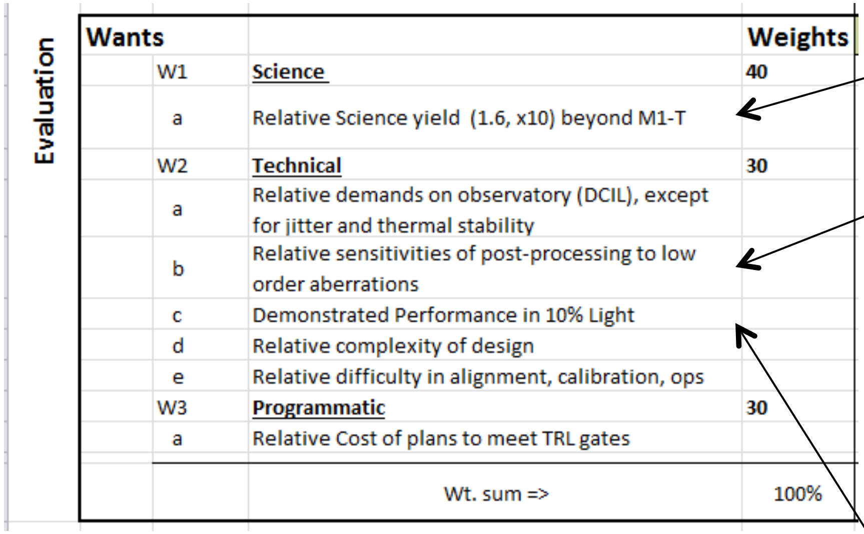
Where is Science Considered?

Where is Technology Plan and Risk Considered?

Risk of not meeting Threshold

Oppty: Science if Jitter lower, Speckle subtraction better

Criteria: Wants

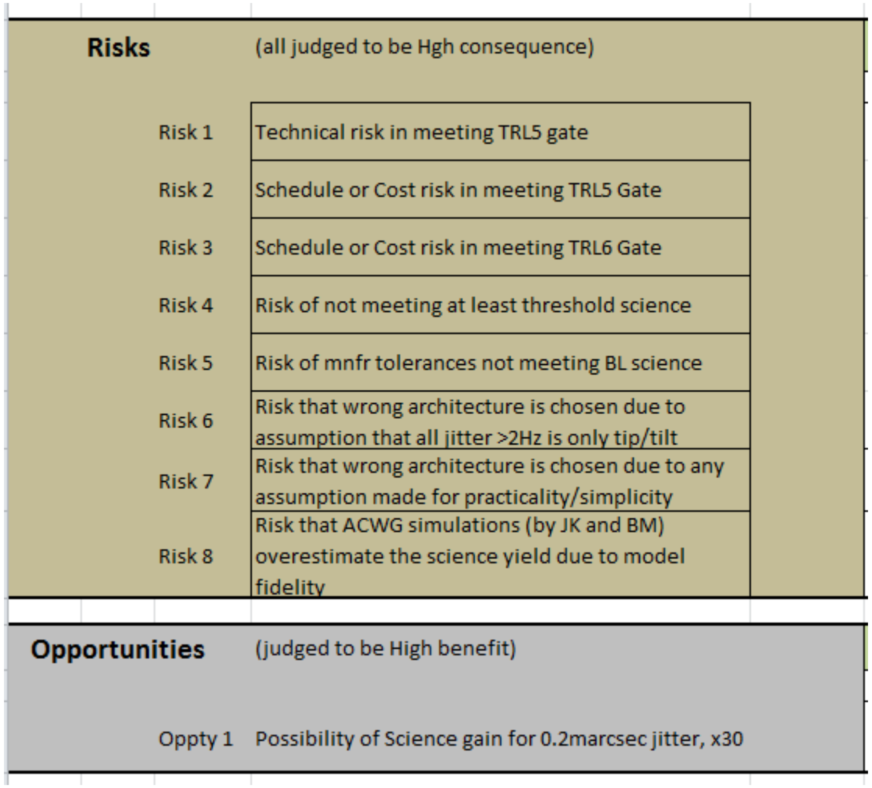


Evaluation

Wants			**Weights**
	W1	**Science**	**40**
	a	Relative Science yield (1.6, x10) beyond M1-T	
	W2	**Technical**	**30**
	a	Relative demands on observatory (DCIL), except for jitter and thermal stability	
	b	Relative sensitivities of post-processing to low order aberrations	
	c	Demonstrated Performance in 10% Light	
	d	Relative complexity of design	
	e	Relative difficulty in alignment, calibration, ops	
	W3	**Programmatic**	**30**
	a	Relative Cost of plans to meet TRL gates	
		Wt. sum =>	100%

- Relative Science yield beyond the threshold “Must”
- Post processing algorithms required to remove dark hole speckles, and degree of speckles sensitivity to optical low-order aberrations (static and dynamic). How sensitive are the dark holes of the technologies to these aberrations?
- Demonstrated performance in 10% light: what has been accomplished through investments to date?

Criteria: Risks and Opportunities

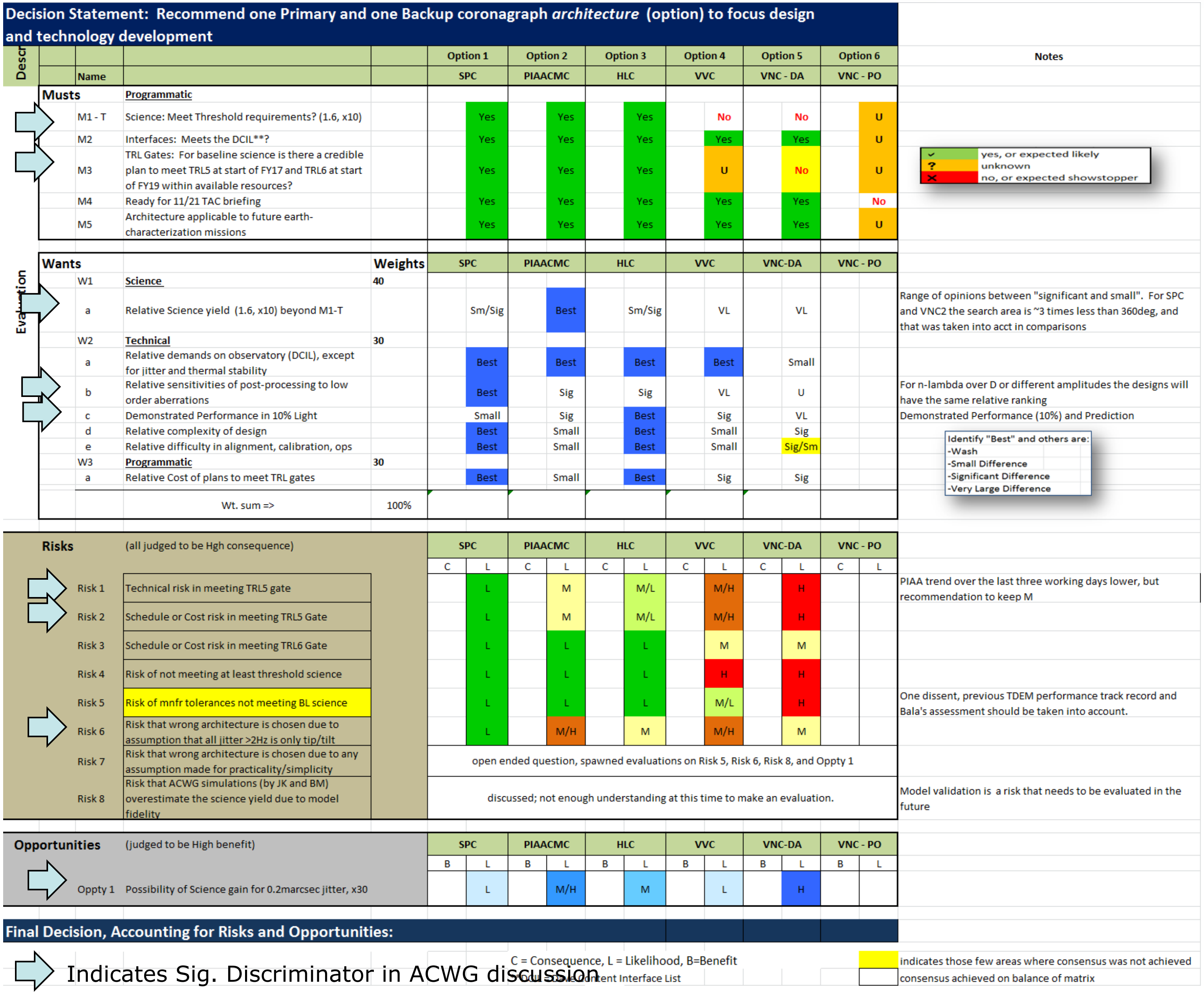


Risks	(all judged to be Hgh consequence)
Risk 1	Technical risk in meeting TRL5 gate
Risk 2	Schedule or Cost risk in meeting TRL5 Gate
Risk 3	Schedule or Cost risk in meeting TRL6 Gate
Risk 4	Risk of not meeting at least threshold science
Risk 5	Risk of mnfr tolerances not meeting BL science
Risk 6	Risk that wrong architecture is chosen due to assumption that all jitter >2Hz is only tip/tilt
Risk 7	Risk that wrong architecture is chosen due to any assumption made for practicality/simplicity
Risk 8	Risk that ACWG simulations (by JK and BM) overestimate the science yield due to model fidelity
Opportunities	(judged to be High benefit)
Oppty 1	Possibility of Science gain for 0.2marcsec jitter, x30

- Risks account for uncertainties in the prior evaluations:
  - In the Musts: credible plan, threshold science
  - In the Wants: the relative cost, the science beyond the Must)
- Also considered any parameters in the decision matrix to which the trade evaluations may be sensitive (e.g., jitter)

- Opportunity: considers improved science yield if the actual jitter is lower, and speckle subtraction is better

Results: Full Trade Matrix



Decision Statement: Recommend one Primary and one Backup coronagraph *architecture* (option) to focus design and technology development

Descr		Name			Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Notes
					SPC	PIAACMC	HLC	VVC	VNC - DA	VNC - PO	
	Musts		**Programmatic**								
⇨		M1 - T	Science: Meet Threshold requirements? (1.6, x10)		Yes	Yes	Yes	No	No	U	
		M2	Interfaces: Meets the DCIL**?		Yes	Yes	Yes	Yes	Yes	U	
⇨		M3	TRL Gates: For baseline science is there a credible plan to meet TRL5 at start of FY17 and TRL6 at start of FY19 within available resources?		Yes	Yes	Yes	U	No	U	
		M4	Ready for 11/21 TAC briefing		Yes	Yes	Yes	Yes	Yes	No	
		M5	Architecture applicable to future earth-characterization missions		Yes	Yes	Yes	Yes	Yes	U	
Evaluation	**Wants**			**Weights**	SPC	PIAACMC	HLC	VVC	VNC-DA	VNC - PO	
		W1	**Science**	40							
⇨		a	Relative Science yield (1.6, x10) beyond M1-T		Sm/Sig	Best	Sm/Sig	VL	VL		Range of opinions between "significant and small". For SPC and VNC2 the search area is ~3 times less than 360deg, and that was taken into acct in comparisons
		W2	**Technical**	30							
		a	Relative demands on observatory (DCIL), except for jitter and thermal stability		Best	Best	Best	Best	Small		
⇨		b	Relative sensitivities of post-processing to low order aberrations		Best	Sig	Sig	VL	U		For n-lambda over D or different amplitudes the designs will have the same relative ranking
⇨		c	Demonstrated Performance in 10% Light		Small	Sig	Best	Sig	VL		Demonstrated Performance (10%) and Prediction
		d	Relative complexity of design		Best	Small	Best	Small	Sig		
		e	Relative difficulty in alignment, calibration, ops		Best	Small	Best	Small	Sig/Sm		
		W3	**Programmatic**	30							
		a	Relative Cost of plans to meet TRL gates		Best	Small	Best	Sig	Sig		
			Wt. sum =>	100%							

Legend:
- ✓ yes, or expected likely
- ? unknown
- ✗ no, or expected showstopper

Identify "Best" and others are:
- -Wash
- -Small Difference
- -Significant Difference
- -Very Large Difference

	Risks	(all judged to be Hgh consequence)	SPC		PIAACMC		HLC		VVC		VNC-DA		VNC - PO		Notes
			C	L	C	L	C	L	C	L	C	L	C	L	
⇨	Risk 1	Technical risk in meeting TRL5 gate		L		M		M/L		M/H		H			PIAA trend over the last three working days lower, but recommendation to keep M
⇨	Risk 2	Schedule or Cost risk in meeting TRL5 Gate		L		M		M/L		M/H		H			
	Risk 3	Schedule or Cost risk in meeting TRL6 Gate		L		L		L		M		M			
	Risk 4	Risk of not meeting at least threshold science		L		L		L		H		H			
	Risk 5	Risk of mnfr tolerances not meeting BL science		L		L		L		M/L		H			One dissent, previous TDEM performance track record and Bala's assessment should be taken into account.
⇨	Risk 6	Risk that wrong architecture is chosen due to assumption that all jitter >2Hz is only tip/tilt		L		M/H		M		M/H		M			
	Risk 7	Risk that wrong architecture is chosen due to any assumption made for practicality/simplicity	open ended question, spawned evaluations on Risk 5, Risk 6, Risk 8, and Oppty 1												
	Risk 8	Risk that ACWG simulations (by JK and BM) overestimate the science yield due to model fidelity	discussed; not enough understanding at this time to make an evaluation.												Model validation is a risk that needs to be evaluated in the future

	Opportunities	(judged to be High benefit)	SPC		PIAACMC		HLC		VVC		VNC-DA		VNC - PO	
			B	L	B	L	B	L	B	L	B	L	B	L
⇨	Oppty 1	Possibility of Science gain for 0.2marcsec jitter, x30		L		M/H		M		L		H		

Final Decision, Accounting for Risks and Opportunities:

C = Consequence, L = Likelihood, B=Benefit

**DCIL = [illegible] Content Interface List

🟨 indicates those few areas where consensus was not achieved

☐ consensus achieved on balance of matrix

⇨ Indicates Sig. Discriminator in ACWG discussion

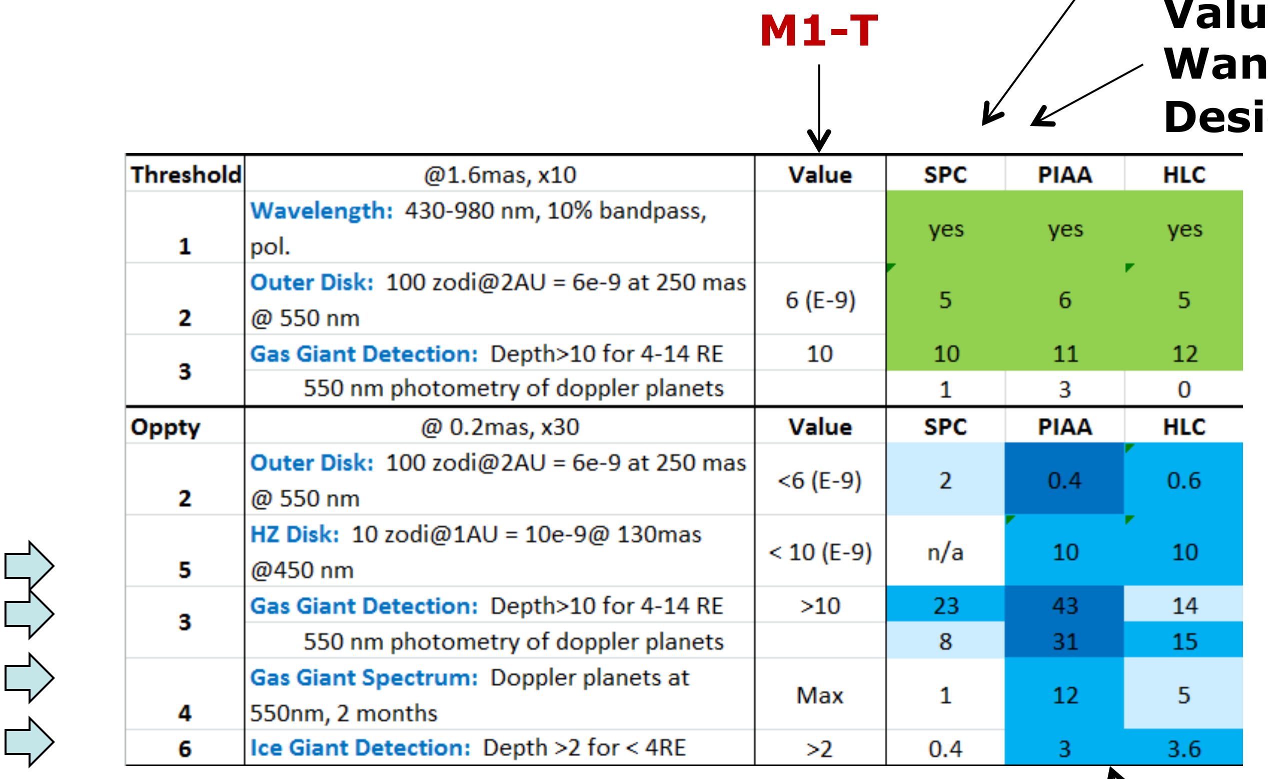
- Scores entered as group
- Consensus sought but not required; no dissent received
- Consensus reached after ~24 hours of group discussion on all points but those indicated in yellow 🟨
- Other colors for evaluation added afterwards for presentation clarity

Results (Opportunity): Greater Science Yield for Lower Jitter, Greater Speckle Suppression

- Revisit Opportunity Science:

Colors indicate pass/fail vs Threshold

Values indicate the Science Want "Beyond the Must" for Design Point (1.6mas, x10)



M1-T

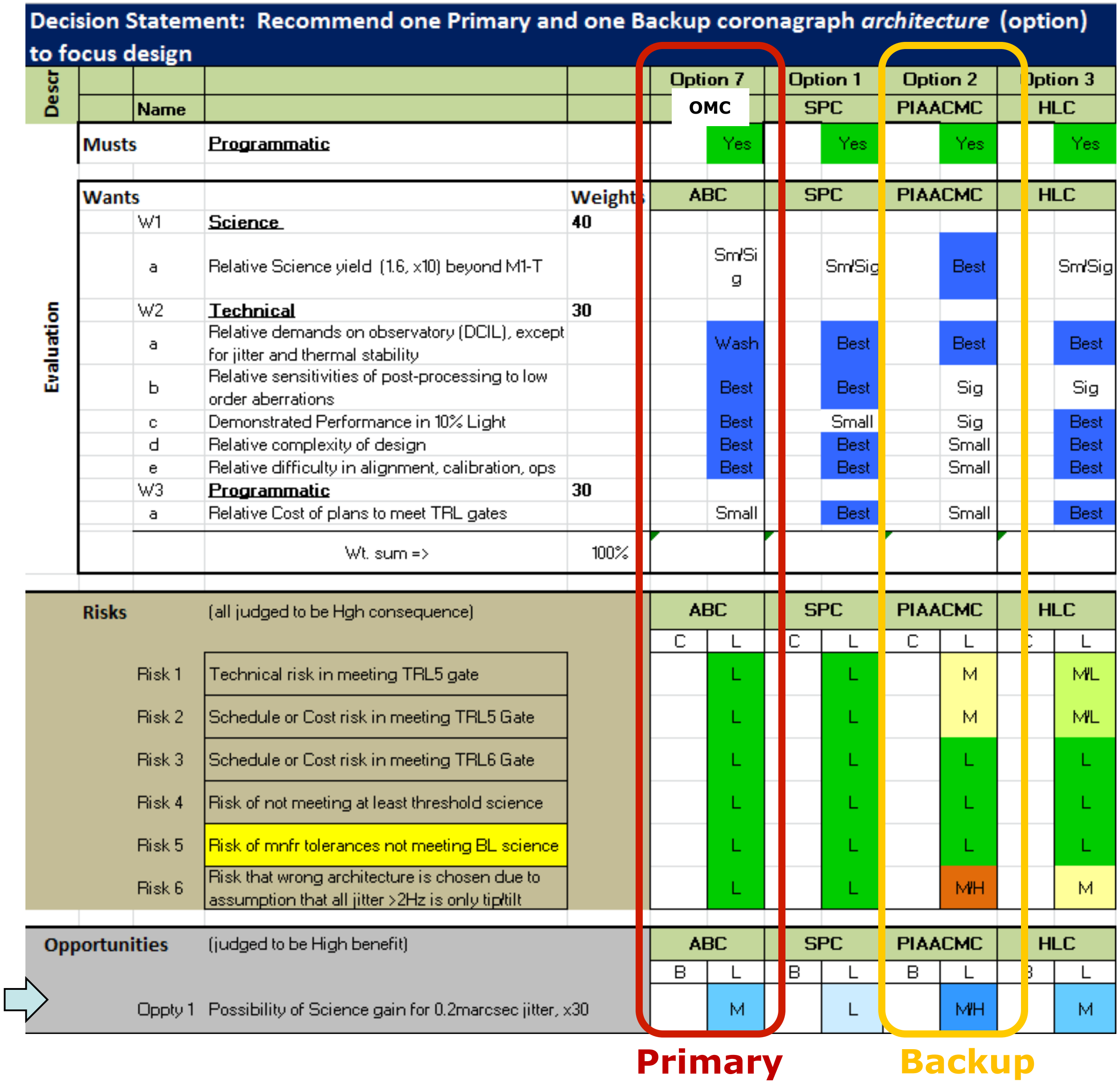
Threshold	@1.6mas, x10	Value	SPC	PIAA	HLC
1	**Wavelength:** 430-980 nm, 10% bandpass, pol.		yes	yes	yes
2	**Outer Disk:** 100 zodi@2AU = 6e-9 at 250 mas @ 550 nm	6 (E-9)	5	6	5
3	**Gas Giant Detection:** Depth>10 for 4-14 RE	10	10	11	12
	550 nm photometry of doppler planets		1	3	0
Oppty	@ 0.2mas, x30	**Value**	**SPC**	**PIAA**	**HLC**
2	**Outer Disk:** 100 zodi@2AU = 6e-9 at 250 mas @ 550 nm	<6 (E-9)	2	0.4	0.6
5	**HZ Disk:** 10 zodi@1AU = 10e-9@ 130mas @450 nm	< 10 (E-9)	n/a	10	10
3	**Gas Giant Detection:** Depth>10 for 4-14 RE	>10	23	43	14
	550 nm photometry of doppler planets		8	31	15
4	**Gas Giant Spectrum:** Doppler planets at 550nm, 2 months	Max	1	12	5
6	**Ice Giant Detection:** Depth >2 for < 4RE	>2	0.4	3	3.6

3 leaders have different science strengths

Can we choose a primary architecture that plays to combined strengths?

Colors indicate degree of Science Benefit for Oppty (0.2mas, x30)

Final Trade Evaluation considering OMC=Option 7



Decision Statement: Recommend one Primary and one Backup coronagraph *architecture* (option) to focus design

Descr					Option 7		Option 1		Option 2		Option 3	
		Name			**OMC**		SPC		PIAACMC		HLC	
	Musts		**Programmatic**			Yes		Yes		Yes		Yes
Evaluation	**Wants**			**Weight**	ABC		SPC		PIAACMC		HLC	
		W1	**Science**	**40**								
		a	Relative Science yield (1.6, x10) beyond M1-T			Sm/Sig		Sm/Sig		Best		Sm/Sig
		W2	**Technical**	**30**								
		a	Relative demands on observatory (DCIL), except for jitter and thermal stability			Wash		Best		Best		Best
		b	Relative sensitivities of post-processing to low order aberrations			Best		Best		Sig		Sig
		c	Demonstrated Performance in 10% Light			Best		Small		Sig		Best
		d	Relative complexity of design			Best		Best		Small		Best
		e	Relative difficulty in alignment, calibration, ops			Best		Best		Small		Best
		W3	**Programmatic**	**30**								
		a	Relative Cost of plans to meet TRL gates			Small		Best		Small		Best
			Wt. sum =>	100%								
	Risks		(all judged to be Hgh consequence)		ABC		SPC		PIAACMC		HLC	
					C	L	C	L	C	L	C	L
		Risk 1	Technical risk in meeting TRL5 gate			L		L		M		M/L
		Risk 2	Schedule or Cost risk in meeting TRL5 Gate			L		L		M		M/L
		Risk 3	Schedule or Cost risk in meeting TRL6 Gate			L		L		L		L
		Risk 4	Risk of not meeting at least threshold science			L		L		L		L
		Risk 5	Risk of mnfr tolerances not meeting BL science			L		L		L		L
		Risk 6	Risk that wrong architecture is chosen due to assumption that all jitter >2Hz is only tip/tilt			L		L		M/H		M
	Opportunities		(judged to be High benefit)		ABC		SPC		PIAACMC		HLC	
					B	L	B	L	B	L	B	L
		Oppty 1	Possibility of Science gain for 0.2marcsec jitter, x30			M		L		M/H		M

Primary **Backup**

- Define OMC = Occulting Mask Coronagraph
- Includes SPC+HL masks on different filter wheels
- OMC emerges as strongest candidate for Primary Architecture
- PIAACMC emerges as the candidate for the Backup Architecture

THE HOW

The HOW: Best Practices

- A Facilitator that does not have a stake in the outcome, other than that there IS an outcome. Technically fluent, and outsider status preferred
- A good recorder
- First agree on Decision Statement, and Criteria
- Criteria: Useful to establish SFOM, TFOM, PFOM
  - Science, Technical, and Programmatic figures-of-merit
  - Sub-teams for evaluation of SFOM, TFOM, PFOM
- Careful distinction of description vs evaluation (always in 2 steps)
- Handling consensus and dissent
- In person essential for criteria and final evaluation
- Timeline expectations
  - Takes a while to develop meaningful criteria, options, and analysis that can later become the basis for relative comparison

Working version of Consensus (yes, NASA has a policy)

- In general, consensus decisions can produce stronger and more durable decisions than those by votes or decree.
- However, convergence time can be a factor in consensus decisions – they take too long or do not converge.
- Instead, we suggest (but do not require) a Constrained Consensus method: defined as preferring and striving for consensus in the reasonable time available, else, the leaders make a decision, dissent (if any) is captured and the groups moves on with full support of the decision.
- Will follow 7120.5E, Ch 3.4, "Process for Handling Dissenting Opinion"
  - Three options: (1) Agree, (2) Disagree but fully support the decision, (3) Disagree and raise a dissenting opinion
  - Treat (1) and (2) as consensus for STDT
  - Dissents (3) will be documented and delivered to senior NASA management (APD DD) per 7120.5E

Conclusion

- A rationale decision process is needed when the decision matters
- A good format exists
- A set of best practices are essential
  - Facilitator (informed, unbiased)
  - Focus on criteria
  - Work to consensus in the time available, else, vote or the chairs choose

- I'm glad to give further coaching to a facilitator for any STDT trade process

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