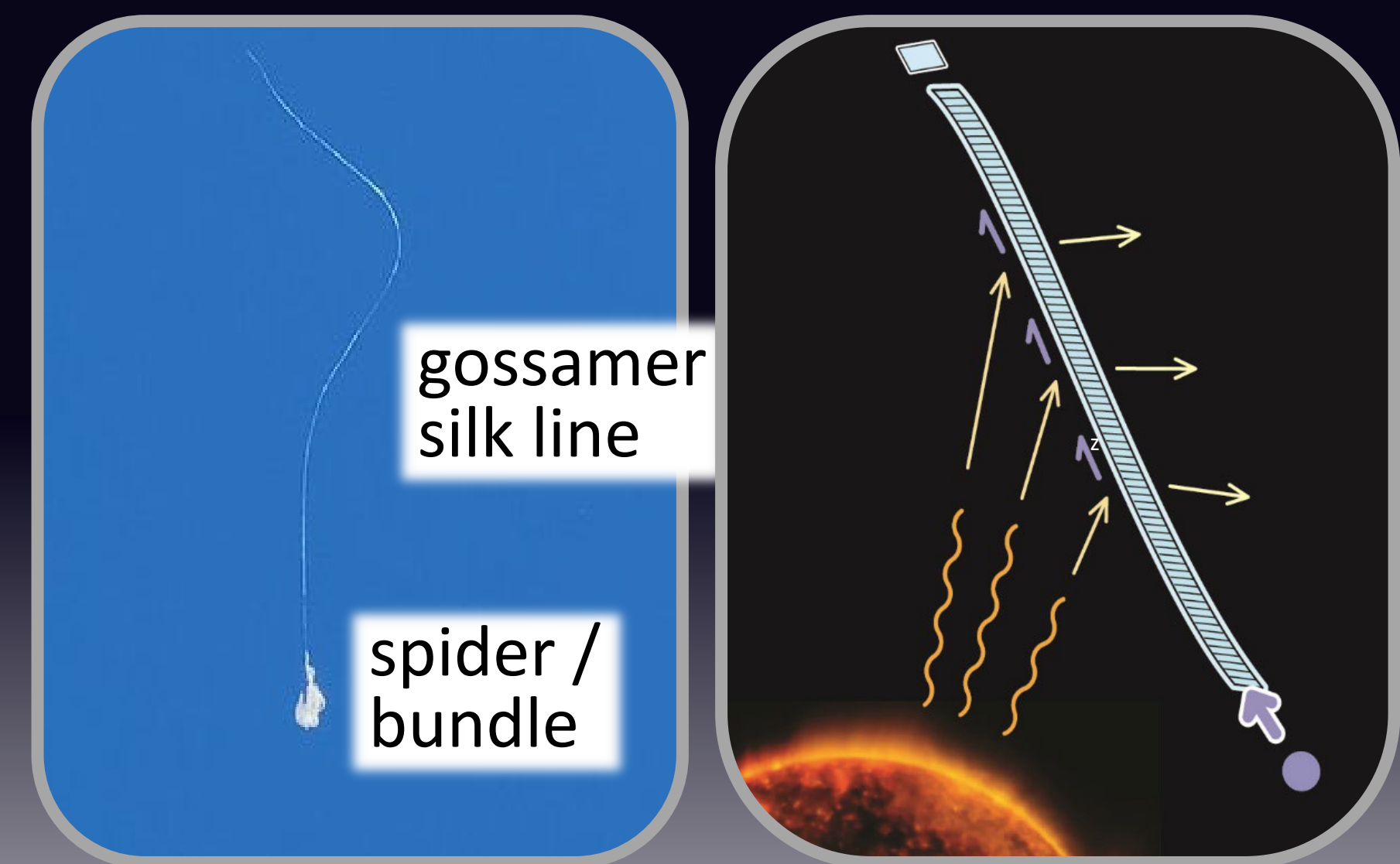


The Ribbon: Structure-Free, Low-Cost Sail for Solar Polar Observation

NASA NIAC Phase I Grant 80NSSC25K7613

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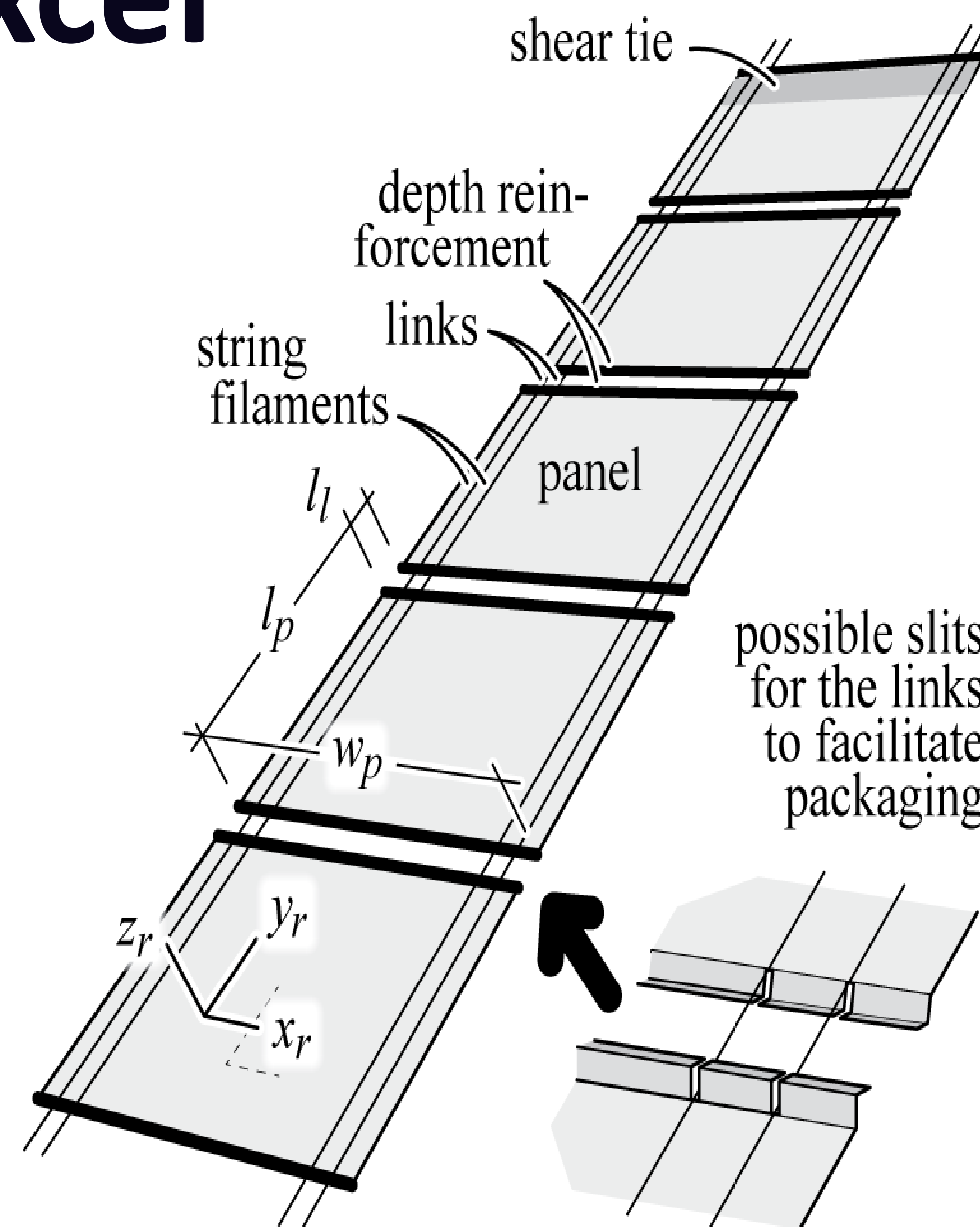


Defined an architecture with steering, developed custom analysis tools, performed optical design, and verified configuration stability

Optical-mechanical design with C++ and MS Excel

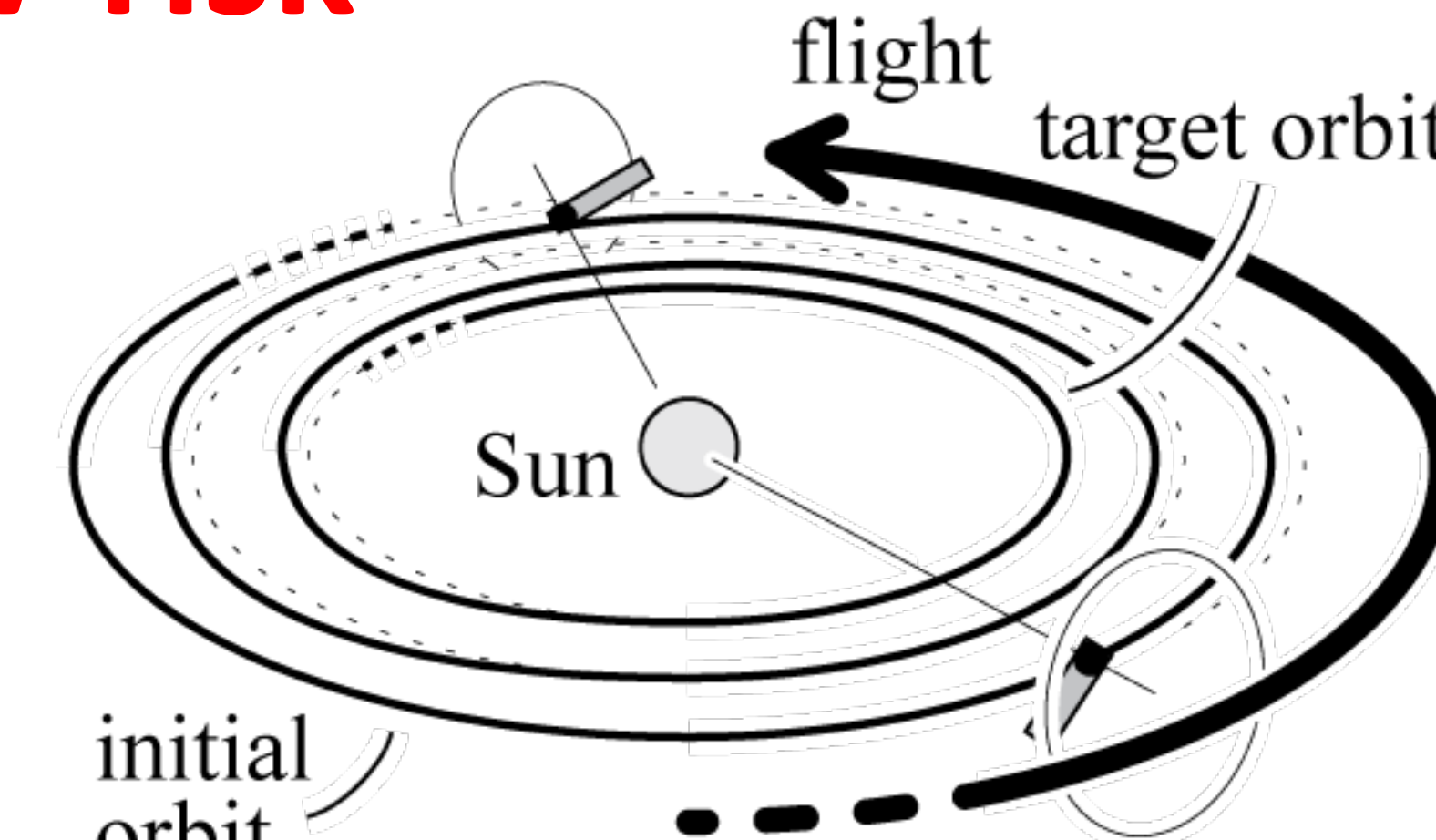
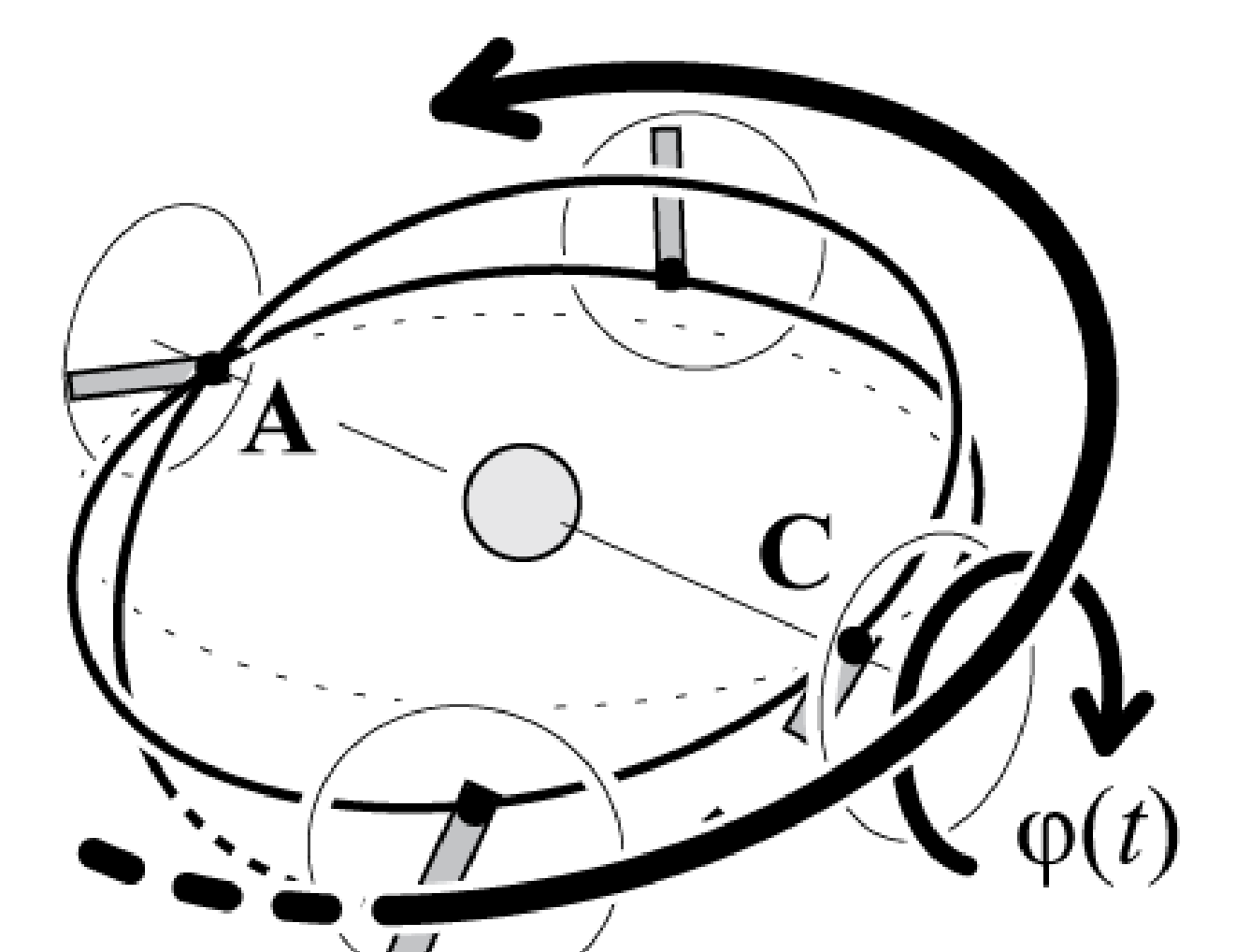
panel coord sys aligned w the panel - xp, yp in-plane; zp thru-align normal
 ribbon coord sys ys is panel target dir, yp, or rot it up about ys to be horiz (light dir)
 solar coord sys xs is ribbon xy, ys rot it up about xs to be horiz (light dir)
 orbit coord sys zs is solar z (the sun line), yo rot it up about zs to be horiz

film properties	2.5 μ m CPI	2.5 μ m	solar reflectance	paF_refl	0.090			
base thk	paF_thk	1454	kg/m ³	paF_rho	0.830			
refractive index	paF_nu	1.58	transmittance	paF_tdt	0.830			
			absorbance	paF_ada	0.080			
panel design & performance			inner area width fraction, 0.1					
geom	width lat. to rbn	pa_w	80	mm	leading edge	pa_wfrad	0.800	
	length l along rbn	pa_l	80	mm	rear edge	pa_wfrad	0.800	
	full panel sfc	pa_A	64	cm ²				
		inner area	each trim					
leading edge width	paF_wl	64	mm	8	mm	CG in pan frm xS	paF_xs	0
rear edge width	paF_wr	64	mm	8	mm	CG in pan frm yS	paF_ys	40
sfc area	paF_A	51.2	cm ²	6.4	cm ²	CG in pan frm zS	paF_zs	0
grating	dir k off axis	paG_kd	0	deg	74	deg		
	grating period	paG_lm	10	μ m	7	μ m		
prism face tilt, back side	paG_fm	15	deg	30	deg			
Sun side	paG_fm	0	deg	0	deg			
full pan inertial	mass	paF_m	0.0362	g	inertias about ps			
avg areal density	paF_rho	5.6492	g/m ²	paF_rho	0.1928			
panel CG in pan frm	xs	paF_xs	0	mm	paF_ys	0.1904		
	ys	paF_ys	40	mm	paF_zs	0.3921		
panel orientation	cross-ribbon tilt	paO_rho	0	deg	illum from below, in the z dir			
	rise (ribbon-axial tilt)	paO_rho	38.015	deg				
	rise angle to fit the thrust	paO_rho	38.015	deg				
area thrusts	in the solar							
inner	F	T Op	E tot	T tot Op				
area	1.45E-25	-1.37E-11	0.00E+0	-2.38E-18				
	4.37E-8	3.51E-27	5.08E-8	3.51E-27				
	2.98E-8	-4.02E-27	3.16E-8	0.00E+0				
trim 1	1	1	6.43E-9	2.28E-10				
	7.21E-10	6.83E-12						
	3.48E-10	1.75E-13						
	4.98E-10	-1.02E-11						
trim 2	7.21E-10	6.83E-12	0.00E+0	0.00E+0	0.00E+0	0.00E+0		
	3.48E-10	1.75E-13	5.08E-8	3.51E-27	1.55E-8	2.78E-27		
	4.98E-10	-1.02E-11	3.16E-8	0.00E+0	6.24E-9	2.16E-27		
total thrust	full thrust F	paF_F	0.0064	μ N				
unless thrust F	paF_F	0.220						
F dir offset fr panel rise	z_rho	38.015	deg					
net linear accel	net linear accel	0.17775	mm/s ²					
rot acc about xpS (pan cg)	rot acc about xpS (pan cg)	0.0000	mm/s ²					
	about ypS (pan cg)	0.0000	mm/s ²					
optical stability	in freq	5.6495	mbz	period	177.04	s		
design tasks - for panel rise aligned to the thrust								
design	trim	grating beta, rear xi						
		for max ypS-rot frequency						



For solar polar observation & other objectives, to achieve:

- Improved thrust efficiencies
- Cheaper, faster missions
- Simplicity**
- Unlimited scalability**
- Low-cost, low-risk R&D**
- Commercial viability**



Target: near-term space flight!!

- Configuration stability & optics } **accomplished**
 - Steering/navigation dynamics & control**
 - Sensitivity: imperfections, perturbations, mitigation**
 - Hardware, workshop procedures, & space flight
- Short term
- Longer term

