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The Geostorm Warning Mission: Enhanced Opportunities Based on New Technology

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Agenda



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- **New-Technology-Based Sailcraft Description**
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- **Conclusions**
- **Acknowledgements**



Key Mission Design Requirements and Principles



Key Mission Design Requirements and Principles	
NMP ST-5 Sub-L1 Sail Project Proposal (1999)	Current (2003)
<ul style="list-style-type: none"> • Ensure first sail project success defined as meeting the flight validation objectives 	<ul style="list-style-type: none"> • Not applicable
<ul style="list-style-type: none"> • Minimize risk of cost overruns 	<ul style="list-style-type: none"> • Same
<ul style="list-style-type: none"> • Minimize total project cost 	<ul style="list-style-type: none"> • Same
<ul style="list-style-type: none"> • Meet user instrumentation measurement requirements key of which are magnetic field vector knowledge to 1° and 100 bps minimum downlink data rate 	<ul style="list-style-type: none"> • Magnetic field vector knowledge, minimum downlink data rate unspecified
<ul style="list-style-type: none"> • Avoid false alarms and missed events 	<ul style="list-style-type: none"> • Not addressed
<ul style="list-style-type: none"> • Provide for launch after completion of the Advanced Composition Explorer (ACE) Mission (2000-2002) 	<ul style="list-style-type: none"> • Same
<ul style="list-style-type: none"> • Provide for achievement of mission goals in presence of sail failure 	<ul style="list-style-type: none"> • Not applicable
<ul style="list-style-type: none"> • Serve as a proof-of-concept for subsequent, additional, operational storm warning missions 	<ul style="list-style-type: none"> • Not applicable
<ul style="list-style-type: none"> • Provide for 18-month operational mission life (3-year goal) 	<ul style="list-style-type: none"> • 3-7 years
<ul style="list-style-type: none"> • Provide storm warning time better than the ~30 min available from a satellite positioned at L1 	<ul style="list-style-type: none"> • L1 warning time minimally acceptable
<ul style="list-style-type: none"> • Not specified 	<ul style="list-style-type: none"> • Continuous data flow, 24 hours per day, 7 days per week
<ul style="list-style-type: none"> • Not specified 	<ul style="list-style-type: none"> • Each measurement broadcast 1 min after measurement completion



Candidate Technologies Having Mission Performance Enhancement Potential for the Geostorm Warning Mission



Technologies and Design Approaches with Potential to Enhance Geostorm Warning Mission Performance					
Sailcraft Elements	Candidate Technologies/ Design Approaches	Enhancement Potential ⁽¹⁾			
		Qualitative ⁽²⁾	Quantitative		
			Mass, kg	Areal Density, g/m ²	% Improvement
• Sailcraft Bus		Medium	30+	6+	16.6
– Structure and Mechanisms	– Vanes used, thruster boom mass eliminated. Requires vane mass addition penalty (See "Sail Propulsion Subsystem, Vanes")	Medium	12	2.2	6.6
– Power	– None specific	Low	< 1	< 0.2	0.5
– Command and Data	– None specific	Low	< 1	< 0.2	0.5
– Telecommunications	– None specific	Low	<< 1	<< 0.2	0.5
– Thermal Control	– None specific	Low	< 1	< 0.2	0.5
– Attitude Control	– See "Propulsion"	Low	< 1	< 0.2	0.5
– Propulsion	– Vanes used, monopropellant Hz propulsion subsystem eliminated	Medium	10	2	5.5
– Propellant/Pressurant	– Vanes used, propellant/ pressurant eliminated	Medium	10	2	5.5
• Sail Propulsion Subsystem (SPS)		High	40+	8+	22.0
– Booms/Structure	– Sub-Tg-impregnated-resin Kevlar inflatable booms	Low	2	0.4	1.0
– Membrane	– 2-micron-thick mylar	High	40	8	22.0
– Vanes	– Vanes (4), including actuators (4), actuator wiring, et al	N/A	(10)	(2)	(5.5)
– Jettisonable Elements	– Carrier module, including boom deployment battery/infrared (IR) heaters/et al	Low	< 5	1	2.7
• Payload/Instrumentation		Low	< 5	1	2.7
– Science/Operational Data	– None specific	Low	< 1	< 0.2	0.5
– Engineering					
• Standard Engineering Diagnostics	– None specific	Low	<< 1	<< 0.2	0.5
• Sail Deployment Diagnostics (Imagers, associated booms, wires, et al)	– Free-flying inspection system, deletion of in-situ system	Low	< 5	< 1	2.7

Notes: (1) Total sailcraft, compared to 1999 NMP ST-5 Sub-L1 Geostorm Sail Project Proposal sailcraft
 (2) High: > 35 kg Medium : 10-35 kg Low: < 10 kg
 () Indicates penalty



Criteria for Sail Selection and Design



Criteria for Sail Selection and Design		
A. Critical (12 Points Each. Total: 48 Points)	B. Important (4 Points Each. Total: 44 Points)	C. Desirable (2 Points Each. Total: 8 Points)
<ol style="list-style-type: none"> 1. Provides for a slow, controlled deployment minimizing film stress and film surface rubbing during deployment and, should full deployment fail to occur, a geometry – to the extent feasible – favorable to degraded flight system performance 2. Offers insensitivity to flight system orientation during sail deployment, an unexpected deployment sequence, or a longer-than-expected time to deploy 3. Minimizes total project technical risk, schedule risk, and cost risk 4. Offers high structural margins (strength and stiffness) under combined loading and deflection conditions, tailorability to add strength where it is needed, and the potential to accommodate less than perfectly straight struts 	<ol style="list-style-type: none"> 1. Minimizes total project cost 2. Accommodates growth in sail dimensions 3. Permits repeatability in manufacturing such that the results of ground analysis and test form a reliable guide to in-flight performance 4. Provides promise for future propulsion subsystem mass reductions, that is, reduced areal mass density, as well as, in particular, reduced structural element linear mass density < 45 g/m. Also Includes the promise for spacecraft bus mass and/or spacecraft expendable reduction 5. Accommodates spin or 3-axis flight system attitude control 6. Technology provider offers experience and demonstrated success with large, inflatable structures 7. Minimizes membrane stress concentrations 8. Minimizes the potential for premature rigidization, both pre- and post-launch 9. Accommodates the introduction of new component technologies 10. Avoids dependence on spacecraft power for deployment and rigidization or, if power is required, minimizes that dependence 11. Maximizes maintenance of the desired deployed geometry under environmentally- and flight-system-induced loads 	<ol style="list-style-type: none"> 1. Tolerance to increasingly hostile environments, in particular, increased thermal loads, radiation, and spacecraft-induced contamination, as well as insensitivity to close proximity to either warm or cold structures 2. Minimizes stowage volume and accommodates stowage shapes 3. Technology provider provides depth and breadth in applicable company resources 4. Offers long shelf life and insensitivity to shelf stowage conditions
<p>Notes: • Criteria shown in priority order, top to bottom, left to right • Total potential score: 100 points</p>		

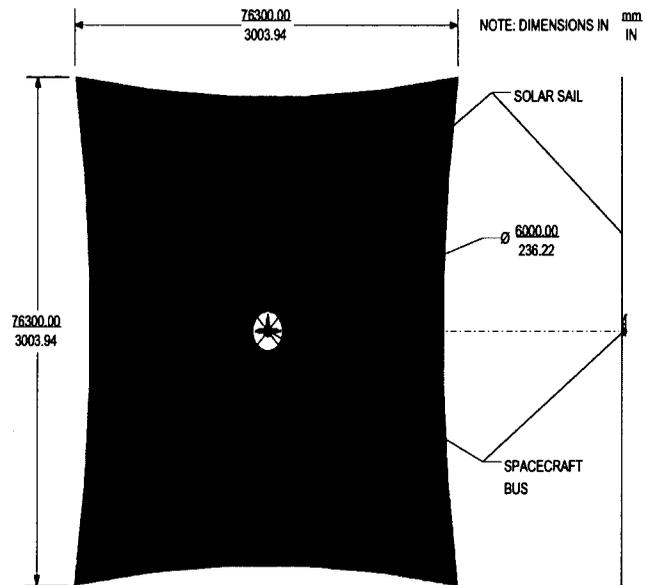


Baseline Sailcraft Description



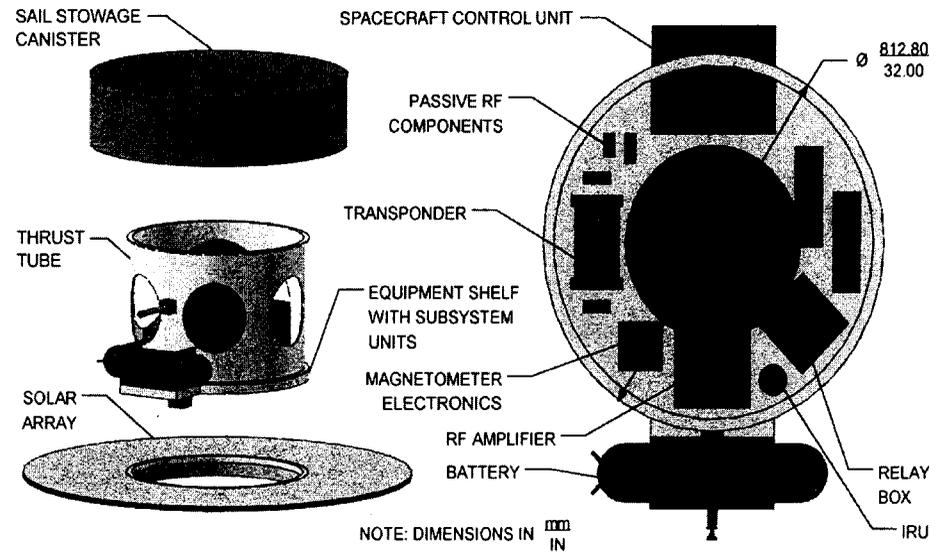
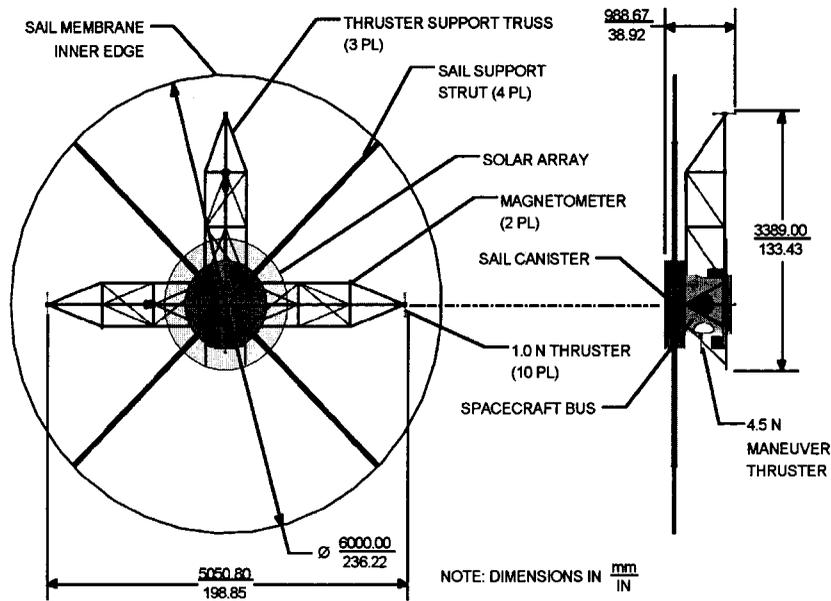
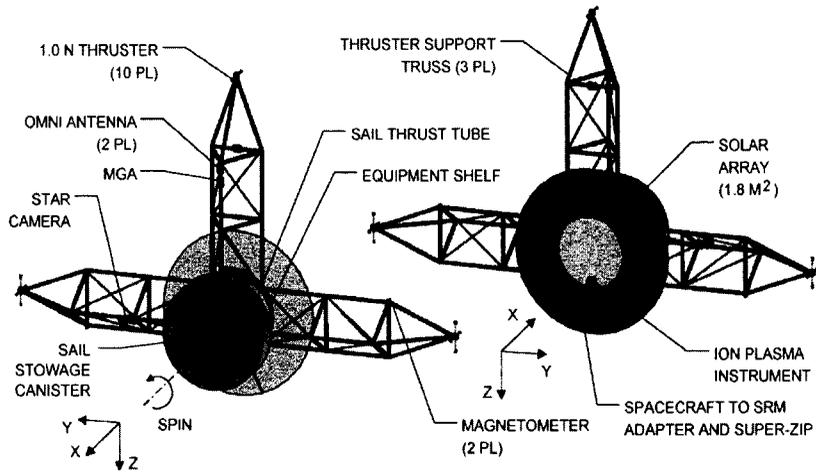
Characteristics

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Baseline Sailcraft Description (Cont'd)



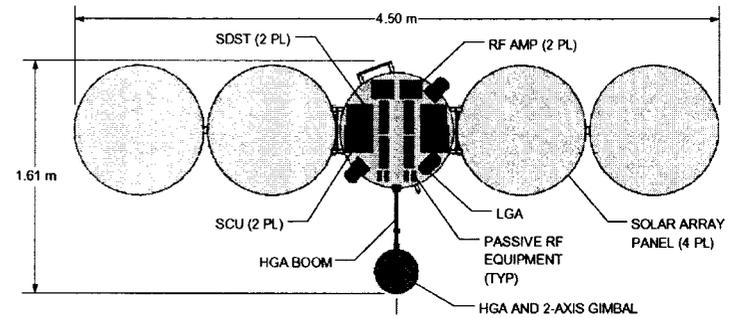


New-Technology-Sailcraft Description

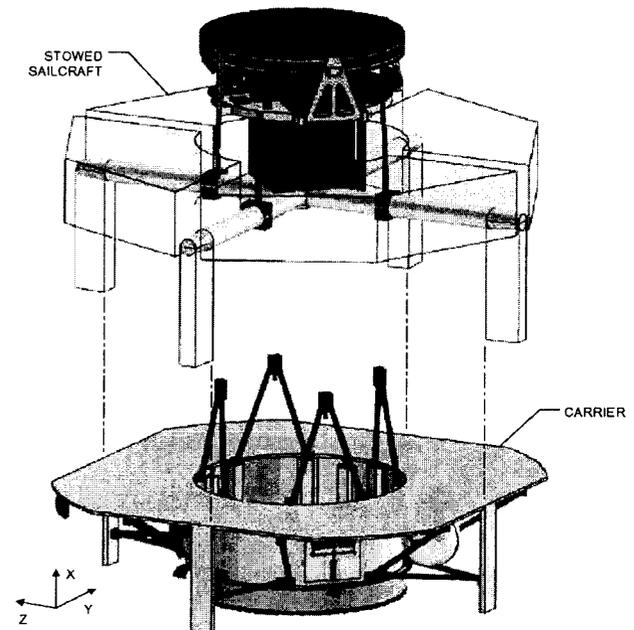
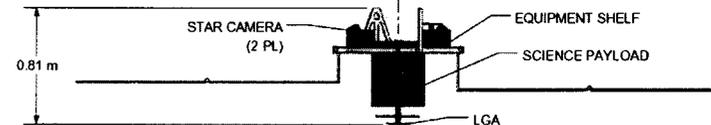


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NOTE: MLI BLANKETS OMITTED FOR CLARITY.





Sailcraft Comparison



Sailcraft Comparison		
Item	1999 NMP ST-5 Sub-L1 Geostorm Sail Project Proposal	New-Technology-Based Geostorm Sailcraft
<ul style="list-style-type: none"> • System Characteristic/Performance Metric <ul style="list-style-type: none"> – Sailcraft Characteristic Acceleration – Operational Station Location on Earth-Sun Line – Sailcraft Areal Density (dry) – Sail Propulsion Subsystem Areal Density – Lifetime – Radiation Tolerance 	<ul style="list-style-type: none"> • 0.169 mm/s² • 0.983 AU (@ EOM) • 36.3 g/m² • 18.9 g/m² • 18 months (3-year goal), propellant limited • Compatible with lifetime goal 	<ul style="list-style-type: none"> • 0.438 mm/s² • 0.974 AU • 9.48 g/m² (assuming use of vanes, carrier module architecture) • 4.9 g/m² (assuming use of vanes) • > 3-5 years, conventional spacecraft element/mechanisms limited • No change
<ul style="list-style-type: none"> • Sailcraft System <ul style="list-style-type: none"> – Mass (dry) – Power (On-Station) – Attitude Stabilization 	<ul style="list-style-type: none"> • 181.4 kg • 193.3 W • Spin 	<ul style="list-style-type: none"> • 94.8 kg • No change • 3-axis (assuming use of vanes)
<ul style="list-style-type: none"> • Sailcraft Bus <ul style="list-style-type: none"> – Structure and Mechanisms – Power – Command and Data – Telecommunications – Thermal Control – Attitude Control/Propulsion 	<ul style="list-style-type: none"> • Small satellite technology • Conventional monopropellant Hz 	<ul style="list-style-type: none"> • No change • Hz system deleted
<ul style="list-style-type: none"> • Sail Propulsion Subsystem (SPS) <ul style="list-style-type: none"> – Booms/Structure – Membrane – Vanes – Jettisonable Elements 	<ul style="list-style-type: none"> • Inflatable UV-rigidized Kevlar. Linear mass density: 41.1 g/m² • 8-micron-thick Kapton • Not used • Inflation system, sail stowage canister 	<ul style="list-style-type: none"> • Inflatable sub-Tg-rigidized Kevlar. Linear mass density: 30.5 g/m² • 2-micron-thick mylar • Used • Carrier module
<ul style="list-style-type: none"> • Payload/Instrumentation 	<ul style="list-style-type: none"> • 3 instruments, 4.5 kg total • In-situ deployment imaging diagnostics system 	<ul style="list-style-type: none"> • No change • Free-flying inspection system



Conclusions



- **TBD**

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