Magnetospheric Constellation

Tracing the flow of mass and energy from the solar wind through the magnetosphere

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1. Executive Summary

The Magnetospheric Constellation (MagCon) mission is designed to understand the transport of mass and energy across the boundaries of and within Earth's magnetosphere using a constellation of up to 36 small satellites. Energy is input into the geospace system at the dayside and flank magnetopause, yet we still do not understand the azimuthal extent of dayside reconnection sites, nor do we have a quantifiable understanding of how much energy enters the magnetosphere during different solar wind conditions. On the nightside, impulsive flows at various spatial and temporal scales occur frequently during storms and substorms and couple to the ionosphere through still unresolved physical mechanisms. A distributed array of small satellites is the required tool for unraveling the physics of magnetospheric mass and energy transport while providing definitive determinations of how major solar events lead to specific types of space weather. MagCon will map the global circulation of magnetic fields and plasma flows within a domain extending from just above the Earth's surface to ~22 Earth radii (RE) radius, at all local times, on spatial scales from 1-5 RE and minimum time scales of 3-10 seconds. It will reveal simultaneously for the first time both the global spatial structures and temporal evolution of the magnetotail, the dayside and flank magnetopause, and the nightside transition region, leading to the physical understanding of system dynamics and energy transport across all scales. It directly addresses LWS program goal #8, "Dynamic Geospace Coupling," while also providing the often required but currently missing global magnetospheric context for ionospheric, thermospheric and inner magnetospheric missions. The technologies required for MagCon are fully developed and flight validated owing to the success of the New Millennium Space Technology 5 (ST-5) Mission. MagCon is ready to be implemented today, with no further technology or instrument development.

2. Science Objectives

The MagCon science objective is to determine how the magnetosphere processes, stores, and releases energy derived from the solar wind-magnetosphere interaction. While these processes are fundamental for understanding the magnetosphere as a plasma laboratory, they are also fundamental for understanding and predicting the space weather of the near-Earth environment. Our lack of knowledge regarding the basic processes occurring within the magnetosphere and at the magnetospheric boundary is a major impediment for transitioning basic scientific knowledge of the geospace system into operational use, and hampers our ability to safeguard the human journey into space. MagCon represents a synergy between understanding of basic physical processes and real-world application of this knowledge for the protection of our technology-dependent society. MagCon seeks to understand the magnetospheric system as a whole, by studying not the individual pieces one-at-a-time, but through multipoint measurements across the entire system. With concomitant ground, low-altitude, solar, and solar wind measurements, MagCon would revolutionize our understanding of the magnetospheric response to dynamic solar wind input and the linkages across systems, and hearken in an era of systems science investigations.

The MagCon science objective can be broken into two over-arching focus areas: 1) mass and energy transfer into the magnetosphere occurring at the magnetospheric boundary; and 2) mass and energy storage, transport and release within the magnetosphere.

The magnetopause boundary, both at the dayside and flanks, is the site where solar wind flow energy is transferred into the magnetosphere. Magnetic reconnection is believed to be the dominant mechanism of energy transfer during southward IMF, yet we do not know the temporal or spatial scales of reconnection. Other coupling mechanisms, including the Kelvin–Helmholtz instability and diffusion induced by wave–particle interactions, provide additional mass and energy transport across the magnetopause boundary. In addition to fundamental questions regarding the interaction, we still do not have a quantitative understanding of energy transfer into the magnetosphere. The best coupling functions are able to account for only 70-80% of the observed energy input, suggesting major gaps in our understanding of the coupling. Substantial questions regarding the input and transfer of energy into the magnetosphere remain, and single point or narrow clusters of observations remain inadequate to the task of understanding when, where, and under what conditions the different modes of energy input occur. Only MagCon offers the ability to finally understand the critical pathways of energy input.

Meanwhile, the magnetotail is a critical volume of geospace for energy storage and releases, where global circulation of magnetic fields and plasmas is regulated in response to changing solar wind conditions. In it, impulsive, localized flow bursts launch and dissipate, powerful electrical currents form and evolve abruptly, and magnetic energy is explosively converted to particle energy. The scale, dynamism, and evolution of the magnetotail have evaded our efforts to observe and understand it using individual spacecraft. Fundamental questions concerning the dynamic response of the magnetotail remain unanswerable with the current observatories.

Magnetospheric Constellation is the logical outgrowth of a sequence of Explorer and STP missions designed to explore plasma transport and energy conversion processes over spatial sizes ranging from the distance to the Sun to the size of low energy particle gyro-orbits. The Magnetospheric Multiscale (MMS) mission will focus on the smallest scale, targeting the microphysical processes of magnetic reconnection. The THEMIS mission targeted a one-dimensional view of the magnetotail, a substantial advancement over the study of complex phenomena using individual spacecraft. Yet this one-dimensional mission was designed to answer a narrowly defined question of which of the two substorm models was acting. MagCon will establish a 2-D array of spacecraft both along and across the magnetopause boundary and the magnetotail, designed to produce for the first time a truly complete understanding of mass and energy transport. Ultimately, it will yield a new foundation on which we shall build a predictive science of next generation magnetospheric meteorology and forecast models, adding to our collective body of knowledge relating to fundamental physics of space weather behavior. It directly addresses LWS program goal #8, “Dynamic Geospace Coupling,” while also providing the often required but currently missing global magnetospheric context for ionospheric, thermospheric and inner magnetospheric missions.

2.1. Energy Input

The MagCon mission will provide observations critical to determining the relative importance and occurrence of different modes of energy transfer and transport during the solar wind–magnetosphere interaction at the dayside and flank magnetopause. A wide variety of models have been proposed to account for that interaction. Some models invoke steady processes such as reconnection along an extended neutral line or widespread diffusion induced by wave–particle interactions. Other models invoke transient local processes such as the Kelvin–Helmholtz instability or bursty reconnection driven by intrinsic magnetopause instabilities. Still other models invoke bursty merging or boundary waves triggered by the highly variable solar wind input, or the significant perturbations introduced into the solar wind by processes occurring within the foreshock.

It is likely that all mechanisms occur, but with a still unknown dependence on both solar wind conditions and the local plasma environment. The signatures of each of the proposed mechanisms are known both theoretically and observationally. Reconnection produces high-speed plasma flows on interconnected magnetosheath–magnetosphere magnetic field lines, whereas diffusion produces a low-latitude boundary layer on closed magnetic field lines, the dimensions of which grow with downstream distance. Bursty reconnection produces flux transfer events, or FTEs – bundles of interconnected magnetic field lines that bulge outward into both the magnetosheath and magnetosphere. The Kelvin-Helmholtz instability produces anti-Sunward-moving waves on the inner and outer edges of the low-latitude boundary layer. Pressure pulses in the solar wind drive waves that propagate dawnward or duskward across local noon in accordance with the spiral/orthospiral IMF orientation. The significance of each proposed mechanism depends on the amount of mass, momentum, and energy it transfers to the magnetosphere as a function of solar wind conditions. These parameters can, in turn, be estimated from the occurrence patterns and spatial dimensions of the phenomena generated by each mechanism. Single point measurements have been able to provide only glimpses into the importance of these various processes. To date, the lack of distributed simultaneous observations has precluded accurate estimates. Although Cluster and THEMIS observations have provided important details on the dynamics of individual, small-scale events, they do not have the instantaneous local time coverage necessary to determine the azimuthal extent of the interaction – a necessary observation for calculating the total energy input to the magnetosphere. Only the Constellation array of spacecraft will provide precisely the observations needed to make the estimates: simultaneous magnetopause, magnetosheath, and solar wind observations over a wide range of local times and solar wind conditions.

An example of how gaps in knowledge of dayside energy transfer inhibits understanding the magnetosphere as a system is the recent discovery that the polar cap potential saturates under certain solar wind conditions. One leading theory suggests a saturation of dayside reconnection, a process neither THEMIS nor Cluster has the capability of understanding. A saturation of dayside reconnection implies that there is a limit on the rate of energy that can be input into the magnetosphere, with obvious implications for magnetospheric energy transfer and near-Earth space weather effects.

The MagCon science objectives for energy input are (1) determine the instantaneous temporal and spatial (particularly longitudinal) extent of energy transfer phenomena; (2) Determine quantitatively the extent of magnetopause reconnection as functions of solar wind conditions; (3) Compare the total amount of input energy as a function of solar wind conditions and determine the dominant mechanism under a specific condition. In conjunction, these observations will provide a decisive answer to some of the most long-standing and controversial questions in magnetospheric physics, and enable a significant leap forward in our ability to model and predict space weather conditions.

2.2. Energy transport, storage and release

The magnetotail loading and unloading cycle of magnetic flux and energy plays a dominant role in magnetospheric activity, ionospheric energy deposition, and inner magnetospheric particle acceleration. The magnetosphere responds to energy input differently under various solar wind conditions, in ways that are not completely understood. For example, under extreme driving geomagnetic storms occur, leading to enhancements of the ring current and significant energy deposition into the atmosphere. Under less extreme but more common conditions, substorms, pseudo-breakups, and BBFs are members of a continuous distribution of impulsive, often localized magnetotail transport. Steady magnetospheric convection and sawtooth events represent intermediate modes of magnetospheric response that are poorly understood. All of these modes couple solar wind energy into the inner magnetosphere and the IT system, and our inability to fully characterize the responses leaves a critical gap in our ability to model and predict space weather impacts.

Mass and energy transport in the magnetotail involves spatial scales ranging from the azimuthal extent of localized fast flows, ~1–2 RE and possibly smaller, up to the largest scales that can be contained in the tail, as well as all temporal scales ranging from a few tens of seconds up to several hours, the typical substorm duration. To understand the flow of mass and energy through the magnetotail, the plasma sheet must be observed over all of these spatial scales simultaneously and continuously. Only a constellation of spacecraft that is distributed over the plasmasheet can accomplish this and provide global "images" of plasma convection, providing definitive, quantitative answers to the questions of how mass and energy flow through the geomagnetic tail.

The plasmasheet is also a region of plasma heating and acceleration, and is known to be a "seed" source of particles for the radiation belts and inner magnetosphere. There is great uncertainty concerning the true spatial, temporal, and energy distribution of the 20–500 keV "seed electrons" in the plasmasheet that are further energized via transport into stronger magnetic field regions. Transport of seed electrons occurs through a combination of processes such as earthward convection, radial diffusion and local acceleration by substorm injections during dipolarization events. An objective of the MagCon mission will be to sort out the relative importance of these various processes in determining the seed populations injected into the inner magnetosphere from the plasma sheet. This is an essential element in developing radiation belt models to predictive capability.

Results from the THEMIS and Cluster missions have highlighted the importance of the nightside transition region located between inner magnetospheric dipolar and stretched tail field lines. In this region flow bursts are braked and deflected, flux pile-up and dipolarization occurs, particles are rapidly energized and injected into the inner magnetosphere, and strong field-aligned currents couple the ionosphere to magnetospheric drivers. It is also a location of discrete auroral arcs, and despite their obvious importance in linking the magnetosphere to the ionosphere, we still do not understand the underlying magnetospheric drivers. A major impediment for determining these drivers is the inability to map ionospheric signatures to the magnetosphere. MagCon will provide the needed multipoint measurements required to finally determine the magnetospheric driver of auroral arcs.

A constellation array of spacecraft provides simultaneous observations of the plasmasheet and inner magnetosphere over a wide range of spatial scales. These observations will enable us to: (1) determine the spatial scales and temporal evolution of mass and energy transport during the different convection modes and in response to changing solar wind conditions; (2) reveal the coupling of the MI system at the transition region and determine the magnetospheric drivers of auroral arcs; and (3) determine the source and energization mechanisms of seed electrons. Thus, the fundamental nature of energy storage, transport and release in the magnetotail will be revealed by the distributed constellation of spacecraft that the MagCon mission will provide.

3. Technical Implementation

Enabling technologies for MagCon have been developed and flight validated for the ST–5 mission that was part of the New Millennium Program. Neither new technology nor instrument development is required. In the following sections we outline several implementations for achieving the MagCon science objectives.

	CBE	CBE w/ cont.	Power
Structure	9.49	10.04	0.00
Power	5.20	5.42	1.10
ACS	0.41	0.42	0.31
Propulsion	2.25	2.32	0.20
C&DH	2.30	2.88	5.00
Comm.	3.20	3.49	3.60
Thermal	0.77	0.81	0.70
Harness	2.97	3.51	0.03
Instrumentation	5.80	6.34	4.50
Totals	**32.39**	**35.22**	**15.44**

Table 1. CBE mass [kg] and power [W] for the MagCon spinners, including ESA, magnetometer and SST instrumentation. Peak communication power is estimated at 14.2 W. Available power is 24 W.

3.1. Spacecraft Bus & instrumentation

The ST-5 spacecraft bus was developed at NASA GSFC as part of the New Millennium Program. It is a small (~25 kg), spin-stabilized spacecraft capable of science investigations from LEO out to beyond geosynchronous orbit. The bus has sufficient mass and power resources to support typical magnetospheric instrumentation such as electrostatic analyzers, solid-state detectors, electric field investigations, and magnetometers. The bus is simple, consisting of high TRL components.

An updated ST-5 bus has been scoped for MagCon. Additional batteries are included for power during eclipses, and some additional shielding has been added for radiation tolerance. Four additional cold-gas microthrusters are included to assist with orbit, attitude and spin control. Pressurizing the original cold gas tank to full pressure increases the onboard delta-V capability for each probe to ~17 m/s, which we believe to be sufficient for the limited orbital maneuvers required for the mission. Cold-gas systems are ideal for a multi-spacecraft build of this type, since they are simple, safe, inexpensive, and do not require special handling, thereby keeping costs down.

To carry out the science investigations outlined in Section 2, the MagCon probes will require a magnetometer and electrostatic analyzer to achieve the minimum science objectives. The addition of a small solid-state telescope would add little cost but would enhance the science return greatly (particularly for an inner magnetosphere petal). ST-5 carried a miniature fluxgate magnetometer mounted atop a small boom. Neither the magnetometer nor the boom require any re-engineering for MagCon, and could be used as designed. The addition of both an electrostatic analyzer and solid state telescope of the size and mass of the THEMIS ESA and SST, for example, is easily accommodated. Table 1 summarizes the current best estimate (CBE) for mass and power usage for the MagCon bus. The low mass contingency for some subsystems is based on the high TRL level of the individual components.

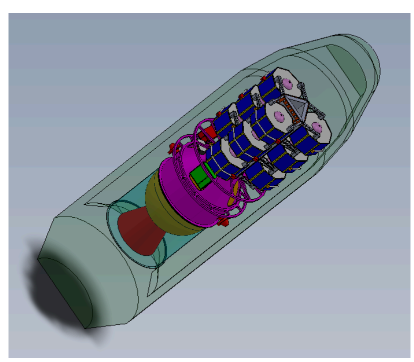

Figure 1. The nine MagCon deployer configuration.

3.2. Carrier

Figure 1 shows nine ST-5 spacecraft mounted atop a STAR37-FM kick motor, within a Taurus fairing. This represents the launch configuration needed for the inner MagCon petal, described below. Other launches would contain 12 spacecraft in a similar configuration, but contained within the larger fairing of a Falcon-9 or equivalent, and with a larger STAR-48B kick motor. The primary function of the carrier spacecraft is to orient itself for a perigee raise and ignite the kick motor. Coarse star trackers, gyros and cold gas propulsion should provide sufficient attitude control. It is not necessary for the carrier to reorient after perigee raise during deployment of the MagCon probes, as each spacecraft would contain sufficient delta-V resources to trim orbits as required. This reduces the complexity (and hence cost) of the carrier. Further information on the requirements levied on the carrier is provided below.

	CBE	CBE w/ cont.
Structure	124.6	141.1
Power	1.6	1.8
ACS	10.0	11.4
Propulsion	81.9	84.4
C&DH	2.5	2.9
Comm.	2.5	2.8
Thermal	1.6	1.6
Harness	5.0	6.3
Totals	**229.7**	**252.1**

Table 2. CBE mass [kg] for the 12 probe deployer.

The dry mass estimate of the 12-probe carrier is shown in Table 2. The mass numbers for propulsion include only the kick motor casing and associated mating structures, and does not include the mass of the cold gas system required for attitude changes, nor the kick motor propellant mass (which are included in Table 3).

3.3. Deployment

A notional deployment scheme is as follows. The Falcon-9 (or equivalent) launch vehicle delivers the carrier directly into an initial orbit with perigee near 150 km and the required science apogee. The carrier separates from the launch vehicle with little to no spin, and reorients using the cold gas propulsion system such that the kick motor burn at apogee will be nominally in the direction of motion. Prior to the kick motor burn the carrier spins up for stability and ignites the motor, raising perigee to ~7 RE. Note that there is no science requirement for precise apogee or perigee, greatly reducing requirements levied on the carrier spacecraft. Once the final science orbit is established following the kick motor burn, the individual MagCon spinners are deployed, with no specific orientation required. Each spacecraft carries sufficient onboard delta-V to reorient so that the spin axis is nominally perpendicular to the ecliptic, spin up or down as required, and impart delta-V as necessary to move ahead of or behind its neighbor, as necessary to achieve the required orbit separations.

The deployment and orbit insertion are designed to be as simple as possible, minimizing complexity, risk, and cost of the carrier while simultaneously meeting the science requirements of the mission.

3.4. Launch Vehicle

A past impediment to a missions requiring multiple launches was the prohibitively high-costs of available launch vehicles. The recent development of the SpaceX Falcon-9 and Orbital Sciences Taurus-II medium launchers makes a multiple launch mission feasible and a mission such as MagCon cost effective. Because the carrier spacecraft by design will not have the ability to perform a plane change, the initial orbit insertion will be directly into the desired orbit inclination, likely to be in the range of 9-12°. A launch from the Cape into this inclination incurs a significant mass penalty, but the baseline payload does

	Apogee			
	9 RE	**12 RE**	**16 RE**	**22 RE**
Total Probe Mass	315	420	420	420
Carrier Mass	215	250	250	250
Total Dry Mass	530	670	670	670
Wet Mass Required	760	1140	1200	1250
Launch Mass	1,290	1,810	1870	1,920
Cape lift margin (15°)	**N/A**	**33%**	**31%**	**15%**
Kwajalein lift margin (9°)	**9%**	**56%**	**54%**	**49%**

Table 3. Total mass rack-up for the different launch configurations, including lift margins. Orbit insertion is assumed to be 150 km x the listed apogee. Perigee raise is to 7 RE.

have sufficient lift margin. We included lift margins from Kwajalein for comparison.

3.5. Data collection & Communication

Data collection from a constellation of up to 36 spacecraft will require some degree of automation in order to keep Phase E costs reasonable. Decreasing the number of personnel required to manage 36 probes is essential for maintaining a cost-effective mission. In the latter half of the mission ST-5 successfully demonstrated a “lights-out” phase of mission operations, whereby the rapidly configurable architecture of the Goddard Mission Services Evolution Center (GMSEC) was allowed to operate the constellation and downlink data without intervention by ground personnel. The success of the ST-5 “lights-out” operations demonstrates a path forward for reducing cost and complexity for mission operations, and we suggest a similar mission operations and downlink paradigm for MagCon.

3.6. Mission Design

Achieving the stated science objectives of MagCon requires multiple spacecraft inside of ~22 RE with azimuthal separations of ~2 RE. To provide maximum flexibility we provide in Table 4 four examples of mission implementation, offering trade-offs between complexity, cost and science. The preferred option is MC33 that contains an inner petal passing through the inner magnetosphere. On the inbound and outbound legs of these elliptical orbits the 9 spacecraft would provide the inner magnetospheric field configuration, enabling for the first time an instantaneous snapshot of the magnetic field on the nightside magnetosphere. The benefits for obtaining such an accurate field state for relating ionospheric observations with magnetospheric drivers is enormous. The cost for this variant is slightly lower than MC36, due to 3 fewer spacecraft and launch on a Taurus rather than Falcon 9 (or equivalent), at the expense of a high radiation environment and likely slightly diminished lifetimes of those probes. One advantage of implementing MC36 or MC24 is that all spacecraft have perigees outside the radiation belt, thereby enabling a long lifetime for these probes, in stable orbits without de-orbit requirements, although the ability to fully characterize the magnetospheric magnetic configuration is diminished. All three launches would be identical as well, although we believe the non-recurring engineering (NRE) costs between the 9 and 12 spacecraft configurations is small. The remaining two options, MC24 and MC21, are designed to achieve the core objectives at lower cost, at the expense of magnetosheath and flank magnetopause science; it would also hamper efforts to capture magnetotail flows. MC21 offers a good balance between overall mission cost and science objectives.

Because of the onboard delta-V the probes could undergo several phases in which the azimuthal separation is adjusted. For example, Phase 1 could study azimuthal separations of 1-2 RE at the dayside magnetopause, the flanks, and plasmasheet. Phase 2 could extend these scale sizes to 2-5 RE, with wider

	MC36	MC33	MC24	MC21	Science objectives
9 @ 9 RE x 400 km		x		x	Inner mag field configuration; magnetospheric driver of auroral arcs; transition region
12 @ 10 x 7 RE	x		x		magnetospheric driver of auroral arcs; Transition region
12 @ 14 x 7 RE	x	x	x	x	Dayside magnetopause; azimuthal extent of flow bursts
12 @ 20 x 7 RE	x	x			Magnetosheath; flank magnetopause; azimuthal extent of flow bursts; flow burst origin and evolution
Cost[1]	$775M	$734M	$504M	$475M	

[1]Estimated phase B-D including 30% contingency and launch vehicle cost (Falcon 9 for 12 probe carriers, Taurus for 9 probe carrier)

Table 4. MagCon orbit configurations, science objectives enabled by each orbit, and estimated mission costs.

spatial coverage. Finally, the spacecraft could be placed equally along the orbits, providing global, instantaneous snapshots of the magnetosphere during an extended phase mission. Other variants include multiple clusters of satellites, for example 3 groups of 4 probes for the 12 probe configurations.

4. Program Cost Estimation & Schedule

We believe that due to the high TRLs of the spacecraft, carrier and instrumentation, combined with the successful validation of required technologies through the ST-5 program, MagCon can be costed to high fidelity. Based on extrapolation of a GSFC grassroots costing of a smaller constellation with the same instrumentation we have provided in Table 5 what we believe to be a realistic phase A-D funding profile for a 36-spacecraft MagCon design and build. Instrument costs are based on build-to-print instruments currently operating.

An important consideration is the extent to which the price of individual components can be reduced – each $100k cost reduction per spacecraft, for example saves $3.6M against the total budget. The avionics package and S-Band transceiver (~$1M/unit) in particular are two components that currently carry a high per-component cost. GSFC is currently working to reduce the recurring costs of these components, although we note that using currently available components the mission is already cost-viable.

	Phase A	Phase B	Phase C	Phase D1a	Phase D1b	Phase D1c	Phase D2	Phase B-D Dollars	Contin gency	Total B-D w/ contingency
	Pre Analysis	Definition	Design	Fab, Func. I&T	Obs. I&T	Prep for Launch	Launch & Checkout			
Phase Duration (months)	8.0	8.0	12.0	48.0	12.0	6.0	6.0			
1.0 Project Management	1.0	1.6	3.0	10.8	1.8	0.6	0.3	18.1	0.3	23.5
2.0 Systems Engineering	0.4	1.8	4.3	10.0	0.4	0.1	0.0	16.6	0.3	21.5
3.0 Safety & Mission Assurance	0.0	0.2	2.3	10.0	1.4	0.1	0.2	14.2	0.3	18.5
4.0 Science/Technology	1.00	3.00	3.00	5.75	0.25	0.00	0.00	12.0	0.3	15.6
5.0 Payload	0.1	1.5	3.0	36.0	3.0	0.3	2.0	45.8	0.3	59.5
6.0 Flight System										0.0
6.1 Carriers	0.8	5.6	12.0	120.0	9.5	3.3	0.9	151.3	0.3	196.7
6.2 Spinner #1	0.3	3.4	5.5	15.0	1.5	1.7	0.5	27.6	0.3	35.9
6.3 Spinner #2-N	0.0	0.0	0.0	99.1	54.0	8.0	3.6	164.7	0.3	214.1
7.0 Mission Ops	0.0	1.0	1.5	5.7	1.0	1.0	1.0	11.2	0.3	14.6
8.0 LVS										
9.0 Ground System	0.0	1.0	1.0	2.0	2.0	0.5	1.0	7.5	0.3	9.8
10.0 I&T	0.0	0.0	0.1	0.0	10.9	1.1	0.0	12.1	0.3	15.7
11.0 E/P O										
Totals	3.6	19.1	35.7	314.4	85.7	16.7	9.4	481.0		625.3
Launch Vehicles								150.0		150.0
Total cost	3.6	19.1	35.7	314.4	85.7	16.7	9.4	631.0		775.3

Table 5. Phase A-D cost estimates for MC36. Average recurring per spinner cost is $4.7M + $1.3M for payload. Average per carrier cost is $50M. Phase E costs are not estimated.

5. Summary

We have provided a set of mission options designed to determine how mass and energy flow through the boundaries of and within geospace. Magnetospheric constellations have been a long-acknowledged requirement for true understanding of the magnetosphere, appearing consistently in previous NASA Roadmaps. Yet to this point technical and cost concerns have postponed development of this mission. The fundamental science objectives of MagCon remain unsolved, and cannot be solved using single spacecraft or groups of tightly clustered spacecraft. With the success of ST-5, THEMIS, and other small satellite platforms, the technical and cost obstacles have been overcome. New, low-cost launch vehicles finally enable a multi-launch mission. The time for MagCon is now.

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