Current Satellite Programs at AeroAstro

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Introduction:
When AeroAstro was founded in 1988, the idea of a company dedicated to microsatellites was unusual, maybe even unique, and certainly radical. There were no recognized "small satellite" companies, programs or funding sources. Fifteen years later, microspace has become the fastest growing and most visible segment of the space marketplace. NASA has converted almost its entire research program to smaller satellites, small geosynchronous satellites have emerged as a new niche for fixed telecomms, both GlobalStar and Iridium, LEO communications systems using constellations of small satellites, are in operation, and several remote sensing small satellite systems are in commercial operation. Small satellites are represented in defense programs also, though none in operational status - yet.

One strength of microspace is that small spacecraft can be built with a minimum of facilities, and the architectures and implementations are simple – and thus inherently reliable, reducing infrastructure requirements. This has led to a great diversity and sheer number of developers - large and small companies, government laboratories, universities and hobbyists, in addition to possibly 100 nations with developing space activities..

Having played a role in popularizing the use of small, low cost and simple spacecraft, AeroAstro is adapting to the broadening of the market, and the increased number and diversity of developers of small, simple space systems. We have clarified the reason that the company was founded - making space accessible to the widest constituency of users – into our corporate vision "making space for everyone". Every activity we consider is measured against that standard – will it ultimately increase the number of people and organizations who have access to space?

This vision has led us into four major initiatives:

- SPORT – the Small Payload ORbit Transfer module for space transportation
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- KitCore – a modular spacecraft architecture which helps enable larger numbers of users to build their own spacecraft. Coupled with radios, sensors and other low cost, highly miniaturized component products which can be used a wide variety of spacecraft, KitCore is an ongoing process of providing another way to access space.

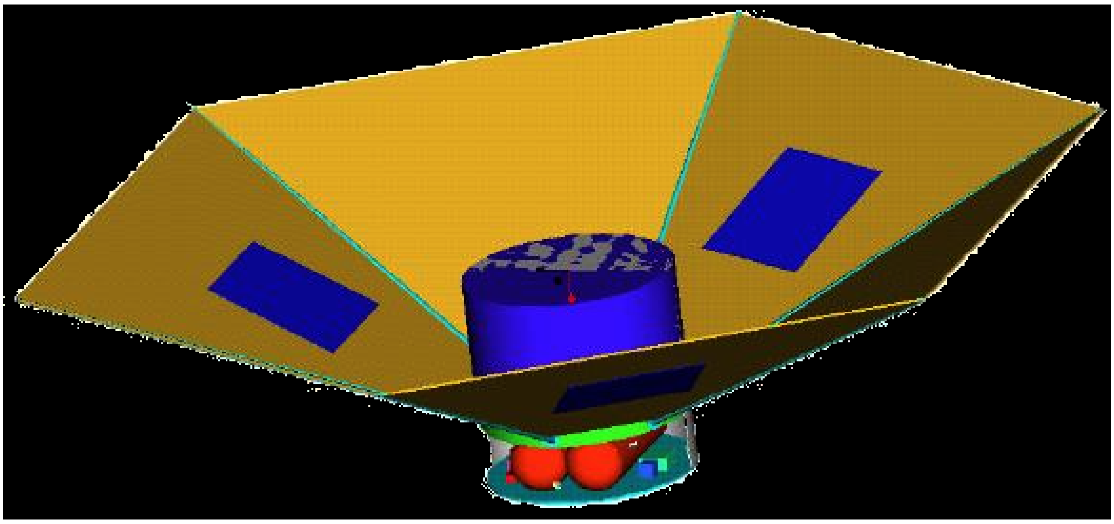
- Complete spacecraft systems for users who prefer not to build their own, and for more complex missions. These systems, built at AeroAstro, exploit our KitCore architecture and add-in components.

- SENS – a simple, low cost, global, near real time digital messaging service, scheduled to go into service for all of North America in early '03 with global service coming on-line region-by-region over the subsequent 2 years.

I. SPORT: Small Payload ORbit Transfer Vehicle

Historically, small satellite programs have depended upon very low cost launch accommodations – often priced below benchmarks of large payloads (~ $10,000 per kg). Early microsatellites were launched on STS (Space Shuttle) and Ariane for tens of thousands of dollars. But dedicated small launch vehicles like Pegasus cost typically ten times more than many contemporary small satellites. And launches on Ariane ASAP, and similar emerging accommodations on Delta and the H-IIA rocket, while affordable and frequent, mostly go to Geosynchronous Transfer Orbit (GTO) – not the Low Earth Orbit (LEO) micro, nano and pico satellites (up to 100 kg, up to 10 kg and up to 1 kg respectively) require.

SPORT is a nanospacecraft coupled with two propulsion systems – one chemical, and one aerodynamic. Riding at low cost on any GTO insertion, SPORT can host a small satellite ranging from a few kilograms up to hundreds of kilograms. After insertion at GTO, chemical propulsion is used to lower perigee to a region of slight aerodynamic drag, around 100 to 200 km. A large drogue is deployed, about 100 times larger in cross section than the SPORT / payload satellite combination. Aerodynamic drag at perigee slowly erodes apogee over tens of orbits. 99% of the drag, and heat, is dissipated on the drogue itself, so that there is no significant mechanical or thermal load on the payload.



Microsatellite (blue cylinder) shielded by the drogue (Gold)
with the SPORT spacecraft beneath it

When the apogee has descended to the desired circular orbit altitude, the drogue is ejected. Its very low ballistic coefficient, and gossamer structure, enable it to reenter and completely oxidize, high up in the atmosphere. The SPORT module then once again uses its chemical propulsion system to raise perigee and thus circularize the orbit at the desired (LEO) altitude. Reducing the chemical propulsion ΔV requirement by about a factor of ten makes SPORT a highly efficient, and hence practical, means of GTO to LEO, and by extension earth to LEO, transportation.

The same SPORT system can transport micro and nanosatellites from Molniya insertion to sun synchronous LEO orbits. Without using the drogue, the basic SPORT module is suitable for trajectory changesfrom GTO to interplanetary and one LEO orbit to another (e.g. orbit raising after release at Space Station altitude).

Once on-station, SPORT can either eject its spacecraft payload and force its own reentry and destruction, or it can become the spacecraft bus, supporting a payload of communications, remote sensing, science, technology demonstration or other user-defined payloads.

Geosynchronous insertions are plentiful, and secondary accommodations on those rides are becoming more common. As small satellites evolve ever smaller, the inefficiency of launching them on dedicated launch vehicles will become ever greater. Transportation's economies of scale are driven by physics, not the market nor politics. SPORT unlocks the natural symbiosis of large and small spacecraft – we get to go when and where we want to, and large LVs generate needed extra revenue to hold costs down for their large customers.

II KitCore

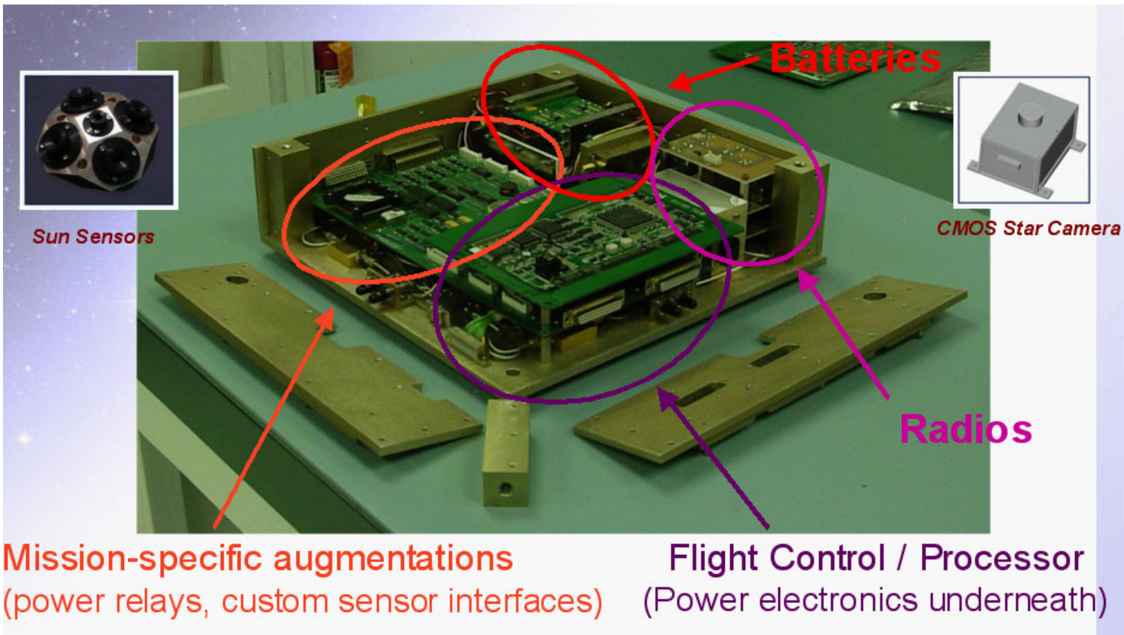
To us old-timers, young engineers don't seem to know how to build things. We soldered each lead onto vacuum tube sockets – grid, screen, plate, cathode, filament. The young generation doesn't know triodes, or any other discrete circuit elements, as intimately as we do, if at all. What they know are modules – processors, memories, MUX, A/D and D/A. They don't design power supplies – they buy a black plastic blob the size of a fingertip, that absorbs whatever power supply is available, and provides perfectly clean DC at the right, constant voltage, under a broad range of loading conditions.

But today's young engineers build systems of complexity we never dreamed of. A chip containing, among other things, a million transistors – 100,000 times more triodes than we ever saw in one place, is but one of hundreds of components on a surface mount board. Circuits with a billion (10^9) gates are common.

Today's microsatellites are a product of this simultaneous increase in complexity, and decrease in focus on discrete components and toward modules which relieve the engineer of the burden of dealing with more fundamental circuit elements. A parallel is in the world of personal computing, where companies, consultants and individuals, configure "custom" computer configurations using discrete modules – mother board, I/O, power supply, operating systems and applications software – as building blocks.

Using the PC as a model, AeroAstro architected a spacecraft from discrete modules, for computing, communicating, powering, commanding, sensing and actuating, and for structure. Rather than try to create a "universal" bus – which is either overbuilt and overly heavy, power hungry, complex and expensive – or inadequate, for the specific task at hand, the user builds up just the system needed, from the building blocks available. The user is relieved of the complexity of each discrete subsystem – radios for example – and is free to architect a more complex, and better suited spacecraft, exactly what each mission requires, from proven modules.

The core of the kit-based spacecraft development system is our Kit-Core spacecraft board, which contains the basic functionality all spacecraft require – computing, communicating, power management, I/O, on a single board. More importantly, it supports a variety of interfaces – to attitude control sensors and actuators, to additional solar panels and batteries, to external radios, to structures, and to payloads, processors, memory and other enhanced capabilities, which any specific mission might require. This is analogous to how a PC motherboard comes equipped to work with a CD-ROM, USB, PCMCIA, a variety of displays, external keyboards and other input devices (eg trackballs, cameras and microphones) and the user selects which of these devices to "add in".



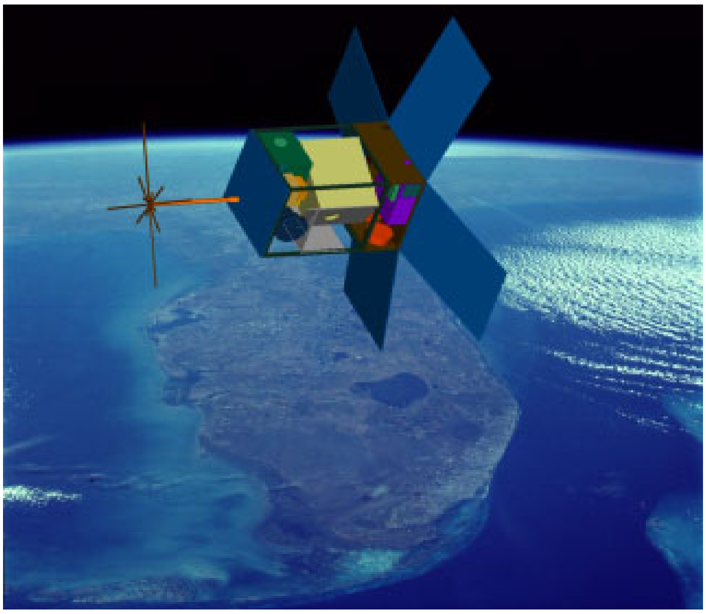
The SPASE spacecraft built by AeroAstro for NASA
incorporates the concepts of the single board spacecraft
plus add-on modules for mission customization

A key attraction of microspace is the ability of small groups and organizations to build their own spacecraft, and thus contain cost and control their own mission. Rather than exploit cost and complexity to try to perpetuate the dependence of the user community on a few contractors, AeroAstro's KitCore is designed to break that dependence. Yet through the use of proven modules and interfaces, and possibly some advice from experienced developers, mission reliability can rival or exceed even professionally built spacecraft.

III Integrated Spacecraft Systems

Not all spacecraft users care to, or are able to, build their own spacecraft. Nor do we expect all spacecraft to be user-built from kits, any more than are PCs or amateur telescopes. Traditionally AeroAstro has been a spacecraft systems developer, and the largest segment of our space business is, and is expected to remain, complete spacecraft tailored to specific missions.

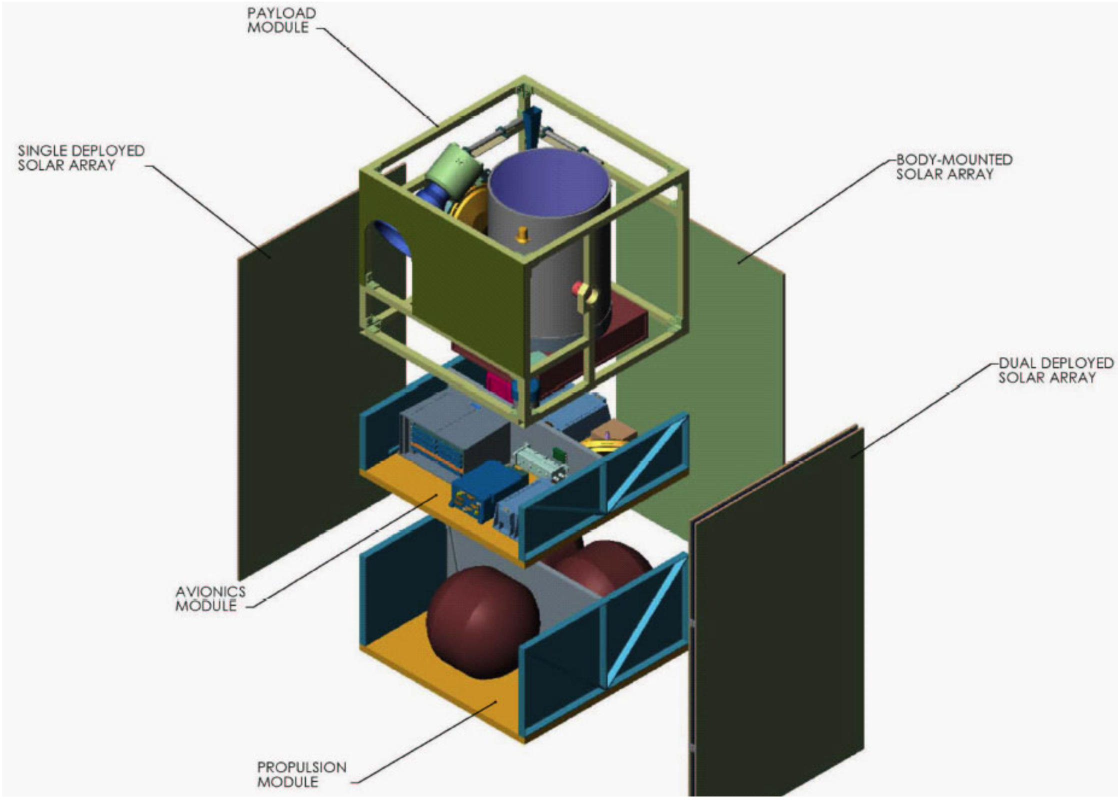
However, our spacecraft architecture has been fundamentally changed by the KITCore philosophy – we build our spacecraft from our own kits. STP-Sat is being built by AeroAstro to support up to five discrete space science and technology payloads for the US Air Force Space Test Program. Our most complex spacecraft, STP has 3-axis stabilization (`0.1°), a 300 watt class power supply, 1 MBit/s downlink, a high-speed commercial processor, virtually full redundancy, all in a package of about 140 kg, using proven subsystems from other programs.



STP-Sat is now under development at AeroAstro for the US Air Force.
It will be launched as a Delta Secondary payload.

STP's design is being used as a starting point for several other missions. Reconfiguring the systems built for STP and other missions, we developed the Micro-Observatory, a half-Pegasus class spacecraft which supports poly- and hyperspectral imaging payloads. Micro-Observatory provides the frequent coverage, application-specific imaging, and control of a dedicated imaging platform, at a mission cost affordable to a new population of users.

Because of its modular design, Micro-Observatory can be reengineered to tailor its capabilities to each user. Many terrestrial products incorporate "custom mass production" – the ability to provide exactly what the consumer wants, but at mass-production pricing. Micro-Observatory adapts this concept to space – a custom built spacecraft without the non-recurring expense of the conventional spec / design / review / build / integrate / test cycle of spacecraft development.



Micro-Observatory Imaging Spacecraft uses modules developed for KIT-Core and STP reconfigured for Remote Sensing

IV LEO Communications

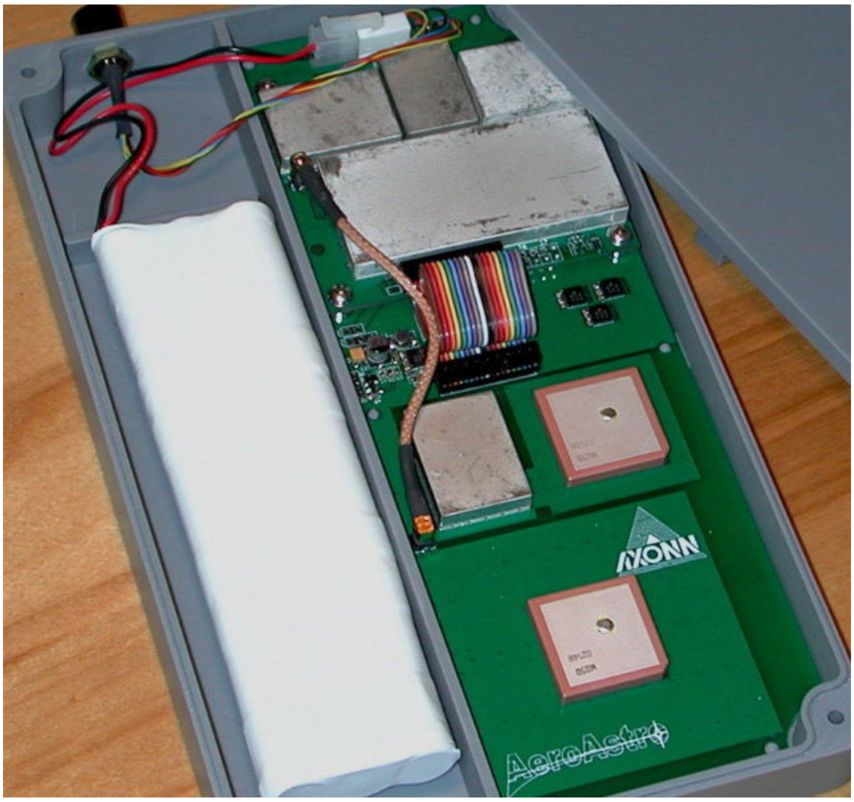
Every commercial LEO comms system launched to date has succeeded technically, and failed as a business. The bankruptcies of the most visible three – Iridium, Globalstar and Orbcomm, add up to investor losses of about $20B ($\$2x10^{10}$). Those failures were only the two most visible out of many. FAI's LEO constellation and TRW's MEO Odyssey, to name just two out of many – failed less prominently, but just as expensively. Coupled with the even more spectacular failures of other components of the communications sector, giants like Worldcom and Global Crossing, AeroAstro's commitment to a global near-real-time messaging system based on a LEO constellation could be interpreted as at best heroic, and at worst, ridiculous.

Human memory is selective. Now that we all use Palm Pilot and Zaurus handhelds, we have forgotten the $ billions lost on the failed Apple Newton and Windows CE platforms. The overwhelming success of the modern digital cell phone has erased from collective memory the fact that Bell Labs abandoned development of the cell phone in 1976 after investing millions of dollars – because they could see no real market for it. The search for the right application, the right niche, for a new technology takes time, money and the ability to fail repeatedly and expensively.

SENS hitchhikes on the existing global network of Globalstar LEO spacecraft – each equipped with wideband linear S-band transponders and high gain antennas. Transmitting at just 100 bits per second, via a 1 second long burst of 2.5 megachip spread spectrum RF, our SENS (Sensor Enabled Notification System) transmitters absorb an almost imperceptible portion of Globalstar bandwidth, to send very brief, one-way messages via the existing network of Globalstar spacecraft and gateways. SENS is a one-way system, and transmitters activate themselves based on either time (ie twice per day) or an event (for instance, a change in temperature of a refrigerated container being trucked cross-country).

SENS is a translation of AeroAstro's space philosophy to a terrestrial use. We constantly seek a solution that is simpler, less capable, cheaper, more reliable, and at least barely adequate to basic user needs. While other comms systems attempted Web access, fax, text messaging, and email, we reasoned that there must be millions of objects in the world that only need to report their status, or position, and which cannot benefit from the web or email. For example, the location of thousands of overland trucks, or millions of shipping containers, or tens of millions of dogs and cats, or hundreds of milliions of children or packages. SENS was architected around just two objectives – very low cost sensor transmitters, and enormous capacity. SENS' current version can support hundreds of millions of users worldwide, the result of tight discipline on message length, and on the use of CDMA to multiplex many low bandwidth messages within a wideband channel. More capacity can and will be brought on-line, within existing bandwidth and without modification to the transmitters, as the market demands.

Via their intrinsic simplicity, the short messages they send, and the remarkable efficiency of the Globalstar system, a self-contained SENS transmitter unit, which we call the STx, which can be purchased today for under $200 in quantity, a price which will eventually fall into the tens of dollars, can work autonomously in the field for up to five years. The position reporting units have no interfaces, no user serviceable parts, and are working the day they are delivered. Installation on a trucked container can be accomplished by an unskilled worker in seconds. All location data, from one object or thousands, is nearly instantly accessible to the client via a private Web account. There is no human interaction with the message except by the client – messages need not be metered nor billed – any more than computer users are billed to download a web page.



This SENS transmitter operates for seven years without maintenance, using integral Lithium-Ion battery and GPS position determination

Spacecraft of 40 years ago revolutionized communications, first via Telstar and eventually via geosynchronous comsats. They revolutionized reconnaissance and our image of the earth – via a combination of LEO and GEO earth imagers. Today's revolution is in navigation – led by the GPS system, soon to be followed by the European Galileo. SENS, by providing location and status information for any object, even objects worth just $100, will play a key role in this navigation revolution – by making position data accessible for very low value, high volume and highly mobile objects, to individual companies and ultimately to the consumer.

V The Next Big Thing

AeroAstro is a small company – 65 people working in Boston, Massachusetts and Ashburn, Virginia. We cannot possibly span the enormous extent of even the micro / nano satellite niche within the space world. Education plays a major role in microspace, and Universities around the world are building spacecraft both for the sake of the experience, and to pursue new capabilities in space. Nanosatellites will play an increasing role in protecting, diagnosing, and ultimately repairing larger spacecraft. Pseudo random clusters and organized constellations of micro and nanosatellites will provide simultaneous field measurements, high gain antennas, and synthetic apertures for earth imaging, geoscience and other applications. The uses for microspace are as diverse as the groups developing them – in industry, government, education, and even in the basements and garages of hobbyists, including Amsat, the radio amateur satellite organization.

This growing diversity of developers and users constitutes the strength and the promise of microspace. Microelectronic technology alone did not cause the enormous growth of the computer industry. The technologies made computing accessible to a fresh, large user community. The applications which now fuel its growth, word processing, spreadsheets, desktop publishing, gaming, web browsing and commerce, instant messaging, and hundreds of application- and enterprise- specific functions in medicine, transportation, distribution, testing and production, to name a few, grew from those new users.

As we put more space capability in the hands of more people, the number and quality of applications for space will grow, and with it our industry. At AeroAstro, we find less and less that we need to invent new applications and sell them to potential users. Increasingly our job is to spend time with new users of space, people and organizations with new ideas for how to use space, who might work with us to implement their concepts and applications. Our job is no longer to preach the value of microspace, but to listen.