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9-602-121
REV: APRIL 9, 2002

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Space Data Corporation

Jerry Knoblach, founder and CEO of Space Data Corporation, was heading into the boardroom when the phone rang. A southern drawl was heard on the line. "I picked up a funny lookin' styrofoam box on the ranch this afternoon. It has a sticker on it that says 'Flight #20, 14 March 2000' and it says I'll get a reward if I call this number. So what is this thing anyway?" "Wow," thought Jerry, "flight twenty! That was nearly a year ago – we never expected to see that payload again."

Jerry and his good friend Eric Frische had started Space Data Corporation several years earlier, aiming to exploit the fact that existing wireless communications systems, such as paging or voice, did not provide coverage to the 20% of the US population that lived in rural or "remote" areas[1]. Their concept was to provide "fill-in" coverage to wireless service providers, using a large number of "SkySites™" – essentially cellular towers in the sky – operating at an altitude of 100,000 feet. The novelty of Space Data's idea lay in the platform they had chosen for these SkySites™ – disposable weather balloons that were launched by the National Weather Service every 12 hours from nearly 70 locations around the US. The plan was to suspend the hardware for sending and receiving signals below these balloons, thereby achieving national coverage.

By the fall of 2001, the design of the combined balloon and transceiver was almost complete, and the FCC had granted Space Data permission to operate. The company had grown to 18 people, including the last recruit, Jerry and Eric's old MIT hallmate David Wu, who had joined the company as President and COO. But as the executive team huddled for its first meeting after hearing the news of the FCC approval, there were still some fundamental questions left to be answered. Discussions with a large paging company had led to an outline service agreement, yet it was not clear if or how Space Data should roll out the service. To David, this question was less of an issue, given his recent meetings with potential investors, many of whom had urged Space Data to skip paging, and go after the voice market. Finally, Jerry had received a call from a large logistics company, interested in using Space Data's technology to track the movement of its fleet of vehicles. With so many questions on the table, it promised to be a long night.

Jerry covered the phone, and called through to Eric, "Hey Eric, another of your babies is about to return home -- flight twenty." Eric smiled – perhaps there was something new to be learned?

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[1] These areas in total, constituted 80-90% of the country's landmass.

Research Associate Jay Wynn prepared this case under the supervision of Professor Alan MacCormack. HBS cases are developed solely as the basis for class discussion. Cases are not intended to serve as endorsements, sources of primary data, or illustrations of effective or ineffective management.

The Idea

It was March 1997 when Eric Frische, an independent toy designer and technologist, received the call from his long time friend Jerry Knoblach. "I've got one you can't refuse," he said, "the idea we've been waiting for… weather balloons!" Eric frowned. What was his good friend talking about? Perhaps he had been out in the sun too long? Eric and Jerry had been looking for an idea to kick-start their own business for more than a decade. Over that time, they had discussed many ideas, ranging from satellite communications services to educational games for children. Weather balloons had never entered into any of the discussions, but Eric figured he should at least hear Jerry out.

Jerry and Eric had lived next door to one another as undergraduates at MIT, but they had followed very different paths during their careers. Eric had always liked ideas that were different, and he loved technology – not big technology, like satellites and supercomputers, but technology that he could build in his garage. Eric's company, Applied Solutions, provided custom design and development services, taking concepts from the drawing board to the factory floor. His projects ranged from new toys for Mattel to custom electronics, and Eric was able to build working prototypes for his clients using a variety of tools that included his own injection molding machine and a computer numerically controlled mill. He was also an inventor, with various patents. He gained experience in telecommunications during his career as an Air Force Captain assigned to advanced telecommunications research at the National Security Agency, and he was also an amateur radio operator.

Jerry Knoblach also loved technology, but unlike Eric he enjoyed the challenge of large, complex high-tech programs such as those found in the realm of satellites and telecommunications. He followed up his undergraduate degree from MIT with an electrical engineering masters degree from the University of Minnesota and an MBA from Harvard Business School in 1992. He went to work afterwards for Orbital Sciences Corporation (OSC). At OSC Jerry served as a marketing and program manager for a variety of projects, ranging from satellite user equipment and ground stations to radiosondes[2]. In one assignment, Jerry managed a successful proposal to the Air Force for developing a new radiosonde known as AMPS, the Advanced Meteorological Profiling System, which added precise Global Positioning System (GPS) and signal processing capabilities to a balloon-borne weather monitoring system. This provided Jerry with the knowledge and expertise that he would later use as the foundation for Space Data.

Eric listened to Jerry's proposal with cautious optimism. "It all started with a call from my uncle," Jerry explained:

> Uncle Ralph is an avid outdoorsman. He had hiked to the top of Pike's Peak – a journey that I preferred to make in my Land Rover! I was amazed to learn that he was calling me from the top of the mountain, because reception on the roads around that area had always been poor or nonexistent. But the answer was obvious – from the mountaintop he had a clear line of sight to cellular towers many miles away, so his signal came through as clear as a bell. As he spoke from atop Pike's Peak, I thought about the AMPS balloon, and a light bulb went on.

Jerry went on to explain what he had learned through his work with the AMPS program. The National Weather Service had been launching weather balloons twice a day from nearly 70 sites throughout the continental U.S. for more than 50 years – more than 70,000 launches annually. Those balloons provided comprehensive weather data for the United States, and Jerry believed that they could also serve a dual role as airborne communications platforms. A weather balloon operating 20

[2] Radiosondes are the weather sensing devices used on board weather balloons to measure wind speed, temperature, pressure, humidity, and other environmental factors.

miles above the Earth could achieve a clear line-of-sight over a vast area, effectively acting as a very, very tall cellular tower. It wasn't clear exactly what they would do with these "balloon-towers" – mobile voice, paging, messaging, asset tracking, telemetry and a host of other ideas came to mind. But Jerry was convinced that there was an opportunity in the making. He recalled:

> I was always a big fan of James Burke's 'Connections' series on PBS, where he takes several disparate ideas, brings them together, and shows you the surprising results of those connections. I thought we might have an opportunity of that sort – combining low-cost transceivers, GPS systems, and weather balloons to create a network that would complement the existing wireless infrastructure. With a quick bit of research, I learned that 80% of the U.S. population is served with wireless coverage from towers located in just 10% of the country's geography - in and around urban areas [see Exhibit 4]. That leaves more than 50 million Americans scattered over wide areas outside cities where the economics of tower-based wireless services don't work. This represented at least $600 million in data services revenue or $6 billion in voice services revenue for Space Data, assuming we split fees with the carriers [see Exhibit 5]. My vision was that a balloon network could do anything that a satellite could do, but at a fraction of the cost and use existing user devices.

The concept seemed to have merit, and Eric trusted his friend's business instincts. It was so ridiculous, it might just work. As Eric recalled:

> I like weird ideas. This seemed to satisfy both Jerry's goal of creating a significant new technology venture and my own personal objective, which was to have fun! I like building things, testing things, and making new ideas work. It was amazing that we actually found something that was an interesting opportunity for both of us.

Building out the Concept

In the spring of 1997 Jerry acquired the Space Data Corporation name that had been abandoned by OSC, who had acquired a company of the same name ten years earlier. The original Space Data Corporation had developed radiosondes for the National Weather Service, and Jerry hoped that the reputation associated with the name would open some doors for them. The "new" Space Data Corporation was incorporated in Arizona in April 1997. After this Jerry and Eric began to conduct serious research, refining the concept and examining the technical challenges that lay ahead.

A host of technical questions had to be answered in order to understand whether the concept was feasible. One of the first challenges was to determine whether a constellation of balloons would hold together at high altitude in order to provide seamless national coverage. Existing balloons from the National Weather Service rose to an altitude of more than 100,000 feet, transmitting meteorological readings along the way and bursting when they reached maximum altitude. No one in the weather service cared whether the balloons drifted much as they rose – that was just another part of the measurements that they took. But variable weather patterns would affect the configuration of the balloon constellation, and therefore, how robust a network based on this constellation would be. So in mid-1997 Jerry began building a computer model to assess the integrity of the balloon constellation, analyzing theoretical drift patterns across different regions of the United States.

The first step in developing such a model was to build a database of wind data for 100,000 feet, the planned operating height. The National Climatic Data Center offered to sell Jerry decades of weather data for a price of $30,000, but as they had not yet received funding, they were reluctant to ante up such a steep fee. So Jerry persuaded a software engineer who had worked with him on a previous project to write an algorithm to extract daily climate information from a public university web site, building a database of information to meet their needs. The resulting models showed that the constellation would experience variable drift rates averaging 35 miles per hour eastward. Some balloons would hover overhead for twelve hours or more while others would drift out of range in just six to eight hours, depending upon geography. The conclusion was that a small number of sites would require balloon launches three or four times a day, but the majority would function with two launches per day, just as the weather service was already doing.

While Jerry worked on the constellation structure, Eric focused his attention on the equipment and systems necessary to achieve control over the balloon in flight. He explained:

> Weather balloons fly straight up, non-stop after launch. They rise to an altitude of over 100,000 feet, where the pressure differential causes the balloon to burst. Our balloons would need to survive for 12 hours or more, so we had to find a way to halt the ascent and level the balloons off at our target altitude of 100,000 feet. The traditional methods of altitude control– "venting" (letting gas out of) the balloon to stop the ascent, and dropping "ballast" (weight) to regain altitude – seemed like the way to go. So I started work on those systems.

In the summer of 1998, Eric attended a conference of the American Institute of Aeronautics and Astronautics (AIAA) on high-altitude balloon systems, meeting the engineers and scientists who managed the launch of balloons for meteorological and research purposes. Shortly afterwards Eric joined the AIAA technical committee for high-altitude balloon research, and went on to join several other official and unofficial balloon groups associated with NASA, the Jet Propulsion Laboratory, and other research organizations. To complement these efforts, Bruce Bollerman, chief engineer from the original Space Data Corporation, was asked to serve as a technical advisor, providing feedback on balloon structure and flight dynamics. Through these interactions, Jerry and Eric gained confidence that the balloon survivability and control issues, while challenging, could eventually be resolved.

This still left the remaining issue of communications capability and protocols. A typical land-based cellular tower operating at a 500-watt power level had a range of about 6 miles, the range being limited by obstacles on the ground. By moving transceivers from land-based towers to balloon-based platforms at 100,000 feet however, the system would achieve a clear line of sight over a much wider area, with a subsequent decrease in power requirements. By mid-1998 Jerry began to examine the issue of the radio frequency "link budget" (the relationship between the amount of power required to transmit and receive at 100,000 feet and the distance that could be reached with such a signal) while Eric continued assessing technical protocols for a light-weight transceiver payload that would interface smoothly with existing wireless communication networks and satisfy regulatory constraints.

During this period, Jerry and Eric continued to hold their day jobs. Despite their time and resource constraints they were able to make substantial progress, sticking to a lean budget and leveraging the assistance of friends and colleagues as they moved the concept forward. By the fall of 1998, Eric was able to put his experience as a patent agent to good use, filing the first patent associated with the Space Data concept and systems. This covered the design of a free-drifting balloon constellation for wireless data transmission and the design of the ballasting, venting, and control systems associated with the ballooncraft. With their patent application underway, background research complete, and computer models in place, the concept began to seem feasible, but the question remained – would it fly? And just as important – could it fly, from a regulatory standpoint?

Facing the Regulators

The federal government exercised regulatory authority across multiple dimensions of Space Data's idea, ranging from launching and operating balloons to radio frequency communications. In the fall of 1998 Jerry began talks with the Federal Communications Commission (FCC) and the Federal Aviation Administration (FAA) regarding the balloon-based communications concept, and he retained a law firm, Morrison and Foerster in Washington, DC to assist with regulatory affairs. With regard to the FAA, they discovered that they were free to operate their system on board existing weather balloons as long as their communications payload weighed less than six pounds. This was considered a safe limit in the highly unlikely event of a collision with an aircraft, presumably causing no more damage than a bird strike. With regard to the FCC, Jerry decided to enlist the help of Al Gross[3], a very respected senior member of the wireless communications community, to provide advice on interactions with the FCC. By February 1999, the FCC Wireless Bureau had granted Space Data an experimental license to test their concept.

FCC regulations played a critical role in the selection of two-way paging as the initial application for the Space Data network, because "Part 24" of the FCC code specifically stated that two-way paging / messaging networks were allowed unlimited antenna heights, therefore allowing balloons to operate under existing guidelines. But because the system would be classified as a mobile wireless service, the FCC restricted the system to only seven watts of transmit power[4] (tower-based "fixed systems" could transmit up to 3500 watts). To provide national coverage from the 70-odd National Weather Service sites in the United States, each balloon would have to cover a circular region almost 175 miles in radius. The key question therefore was whether a 7-watt transmitter could send a signal that far. As long as there was a clear line of sight between the user on the ground and thellooncraft overhead, Jerry's initial calculations seemed to suggest it would. For users located indoors or inside moving vehicles, the answer wasn't yet clear.

The final agency that Space Data had to interface with was the National Weather Service (NWS). With more than 70 launch sites in operation around the United States, Space Data hoped to piggy-back their communications payload onto existing weather balloons. The challenge was to develop a system that did not require changes to NWS' existing operations, while offering them incentives to cooperate. Further investigation revealed the ideal "carrot" – an integrated GPS receiver. Eric already planned to include a GPS unit on the payload to determine both position and altitude, thus allowing the ground antennas to aim at the ballooncraft and maintain contact. The NWS had sought funding from Congress for nearly a decade to incorporate GPS into their weather balloons, in an effort to improve the accuracy of data gathering, but funding had repeatedly been denied. If the NWS would agree to launch Space Data's ballooncraft with their radiosondes from its existing sites across the US, Space Data would provide GPS data to them at no charge, as well as paying for the larger balloon that would be required. The proposal was received favorably by NWS' technical committee, and was passed up the chain for final review and approval.

Refining the Focus

After more than a year of research into the technical feasibility of the concept and the regulatory hurdles they would face, Jerry and Eric prepared their first business plan in February, 1999. Their research confirmed the earlier findings that approximately 20% of the United States population lived and worked outside the range of existing tower-based wireless networks. Given the fixed cost of a

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[3] Inventor of the walkie-talkie and secure wireless communications systems used during World War II.

[4] Space Data was later granted an exemption that reclassified the network, allowing for increased power in the future.

tower was $230,000 without the radio equipment and averaged $875,000 with the radio equipment, it would cost over $20 billion to cover the 90% of non-urban U.S. geography using this method if the Earth were perfectly flat [see Exhibits 6 and 7]. Due to topographic variations it would actually take several times this number.[5] By contrast, Eric had calculated that with currently available technologies, it should be possible to design a simple communications payload appropriate for the two-way paging market that could be manufactured for only $300. Assuming two launches a day every day of the year, the Space Data tower "equivalent" would cost $220,000 per year to run. Critically however, each SkySite™ would cover an area equivalent to more than 850 terrestrial towers.

The initial business plan outlined three primary markets: paging and messaging for customers roaming outside normal areas of reception; paging and messaging for people living in rural communities; and telemetry (machine-to-machine data transfer) for remote devices. Initial subscriber forecasts promised a robust market [see Exhibit 15].[6] Although mobile voice service seemed to be a natural market for a communications platform like Space Data's ballooncraft, the weight and power requirements for a voice-capable system couldn't yet be accommodated. The FAA weight limitation of six pounds, combined with the FCC's initial restrictions on power output, limited the company to low-data rate applications, at least until they could make significant (and time-consuming) technical and/or regulatory progress. An initial foray into paging, messaging, and telemetry therefore made the most sense. As Eric recalled:

> It really wasn't a hard decision. As soon we started to investigate this idea, we realized that we wanted to use the lowest level of technology first. Build a system that we could put up that would pay for itself, and then expand from there, enhancing it over time.

Having decided on paging, messaging, and telemetry, however, a larger question still remained. How would Space Data reach its customers? Would they develop an independent "Space Data" network, with its own pagers and messaging devices? Or was there a way to take advantage of the devices and networks already in use? Jerry recalled:

> The hard battles had already been fought to create a large, dynamic market for mobile paging and voice services. This was the top-down effort to build an entirely new industry, one that took tens of billions of dollars and many decades to create. We didn't want to create an entirely new service that went head-to-head with major players. We wanted to cooperate with them, and work our way up from the bottom to tap into their experience, networks, and customer base. We just had to find a way to use weather balloons to do this.

As a result, Space Data decided not to provide service directly to consumers, but instead, to serve as a "carriers' carrier." They would sell their capabilities to wireless carriers such as Arch, Verizon, Weblink, SkyTel, or any other major player who already operated. This would remove burdens such as customer service and consumer billing from the equation, and allow Space Data to focus only on technology and operations. In effect, Space Data would act much like a cellular tower provider, offering multiple carriers the ability to use their ballooncraft as a telecommunications relay station. Building a system with connections to existing carriers however, required more than just ballooncraft. The interface between the ballooncraft constellation and the wireless carriers would require a Network Operations Center (NOC) to relay data between the carriers and unattended ground stations located at each launch facility. Each ground station would need transmitters and receivers

[5] Merrill Lynch reported that the combined capital expenditures for the top six wireless voice carriers was an estimated $21 billion in 2001, of which a third was targeted at improving coverage. Source: Pitkin, William, Merrill Lynch Equity Research, 4th Annual Tower Summit and Trade Show, October 2001.

[6] Due to the projected decline in traditional one-way paging, Space Data chose to focus exclusively on two-way paging, also known as advanced messaging.

for communicating with the ballooncraft, antenna tracking controllers, communications links with the NOC, and an uninterruptible power supply. The ground stations would maintain the link with ballooncraft, communicating with the NOC. The NOC would provide the interface to carriers' existing networks.

After wading through the 100-page business plan in early 1999, Jerry's father, Mark Knoblach, invested $500,000 in the company. This gave Jerry and Eric the capital they needed to take things to the next level and devote their full time efforts to building the company. Armed with this new money, in June 1999, they attended the ReFLEX mobile communications conference held by Motorola and Glenayre (a base-station equipment manufacturer). They shared their concept with a potential customer, the CTO of SkyTel, for the first time. Jerry reflected upon the response:

> We were a bit paranoid, and didn't really want to tell SkyTel exactly what we were doing. We simply said that we had a satellite-like technology that could provide service to their mobile devices *anywhere* without any modifications required. Their first response was "yeah, right!" I still say to this day that it was only because Eric and I had a couple of MIT degrees that they let us in the door for half an hour. We persuaded the CTO to let us brief their executive team, and after some head-scratching, they decided it might actually work.

Designing the Organization

As 1999 progressed, Jerry and Eric began assembling a board of directors that could provide advice on the major issues facing the company: technology, regulation, funding, and market acceptance. Through Al Gross, they were able to recruit Eric Schimmel, a former Motorola engineer who had served as that company's liaison with the FCC before later becoming a VP of the National Telecommunications Industry Association. Since retiring, he held a State Department appointment to chair the U.S. wireless working groups for the International Telecommunications Union; the branch of the United Nations that sets international telecommunications law. They also recruited David Jones, the general counsel from Hubbard Broadcasting and United States Satellite Broadcasting (USSB), who had extensive experience with the FCC during the introduction of direct broadcast television and with the SEC during the USSB initial public offering. They were able to bring Randy Hoffman on board; Randy had been the CEO of Magellan, a GPS equipment provider, where he had gained extensive experience in building a venture-funded startup. Finally, they brought in Jerry's brother, who was an experienced entrepreneur, venture capitalist, and a member of the Minnesota state legislature. Jerry recalled:

> Our selections for board members were very deliberate. We needed someone to help navigate the rough waters of the FCC regulatory environment, and David Jones and Eric Schimmel were perfect for the job. At the same time, we knew that we would need access to many high-powered technologists both here and abroad, and Eric's networks fit the bill. My brother had run his own company and funded others, so he understood the challenges of building a business from the ground up, which I had never done before. And Randy Hoffman was our shark – he had fought many a battle with the VC community, and had an edge about him that we knew would get put to good use once we started raising serious money.

At the same time, they continued networking in the Industry to build their reputation. In September 1999 they attended a conference in Florida where they met a Motorola VP, Morris Moore, who had led the development of Motorola's first two-way pager. Moore became a staunch advocate of Space Data, along with Jim Page, a VP of Marketing at Motorola. These contacts provided beachheads for gaining access to other companies in the industry to further test their concept.

In December of 1999, Jerry convinced his father and brother to invest another $500,000 in the company. With a team of advisors and directors that could address most of the issues they faced, they now needed a full-time staff to begin executing. The decision was made to first make key hires at senior levels who would take responsibility for building out each functional area. Charlie Tracy from Orbital Sciences, a retired Air Force colonel who had been Deputy Director of all meteorology operations for the Air Force, was recruited as a vice-president to run flight operations, the ground stations, and the interfaces with the FAA and NWS. Jeff Poe from SkyTel was brought on board to manage network development and operations (the NOC) and initially develop the ground stations and Randy West was hired from Maxtor to manage manufacturing and quality control.

By May of 2000 the company had rented a small office in Chandler, Arizona and hired eight new employees. Bringing the entire "core team" on board from the very beginning had seemed like a great idea, but it wasn't without its challenges. Having worked as a two-man team for nearly two years, moving so quickly to ten represented a huge change. Eric remembered:

> We suddenly realized that we weren't the center of gravity in the company any longer. Jerry and I had worked on Space Data for so long that most of what we knew about the business and technology seemed intuitive by the spring of 2000. But here were eight smart new engineers, managers and specialists, each with their own ideas and their own views of the project. So inevitably there was conflict, which was healthy in a way, but it occupied a lot of our time. In most cases, the original plan, idea, or design was adopted in the long run, but not until after it had gone full circle through the thought processes of all of the new members. In retrospect though, it may have been better to hire the core team over time to allow us to bring them up to date on the large amount of research that had occurred to date.

Other problems also surfaced, due to the timing of different activities. The hire of Randy West proved to be premature, as it became evident that the company would not require his manufacturing expertise for over a year. He subsequently left. Additionally, one engineer left as a result of differing "technical philosophies." Eric explained:

> Our concept was somewhat different than that used for traditional high-reliability communication systems. We are using inexpensive disposable components for the payload, with the aim of achieving high reliability at the level of the overall *system*. Some people adapted well to this apparent dichotomy, but others did not. For an engineer who had always approached every task as a perfectionist, our approach was akin to heresy. But perfection costs money and time, and isn't always necessary.

Designing the Concept

By June 2000, the first ballooncraft design was finally ready to test. The initial design consisted of five major subsystems [see Exhibits 8 and 9]. The vent mechanism would allow the balloon to release lifting gas, slowing its ascent and initiating descent to help control altitude. The ballast system would allow the team to raise the altitude of the balloon by dropping excess weight. The GPS unit would provide an accurate reading of both altitude and ground position at all times, allowing the team to track the ballooncraft in flight and eventually recover it. The Digital Signal Processor (DSP) based transceiver would provide communications to and from the ground, drawing power from an on-board battery pack. And finally the parachute would bring the payload safely back to the ground when the balloon burst, allowing the team to recover it and examine how it had operated.

As the first launch approached, Eric and Jerry's nerves began to show. While the simulations and testing they had done at ground level suggested this crazy idea should work, there was no telling what problems they would encounter once they actually put a balloon in the air. As Eric recalled:

> When testing began, we had two major concerns. First, could we get an inexpensive latex weather balloon to survive for over 14 hours - 2 hours to rise and 12 hours to float – at an altitude of 100,000 feet, given the harsh UV environment, and extreme temperatures down to -90C? And second, would our "link budget" prove to be correct. That is, could we really communicate with a two-way email or paging device at a distance of 175 miles with only 2 watts of power[7]? Those were the showstoppers that we needed to prove out fairly quickly.

On June 28th, 2000 the team launched their first flight test (see Exhibit 13 for a list of all test flights). This flight aimed to show whether a balloon could survive the harsh environment at 100,000 feet for an extended period of time, while also testing a "two-balloon" system for maintaining altitude – one would lift the payload to the desired altitude and burst, while the other would provide "neutral buoyancy," maintaining it at this height. Although this was not part of the original design, the "two-balloon" system was strongly advocated by the VP of Engineering because it would eliminate the vent completely, which he viewed as a tough design problem. The flight lasted for over 11 hours, proving the first assumption correct, and demonstrating that a two-balloon system could work, although the altitude varied considerably. Some of the staff felt this was not the best long-term solution however, given the National Weather Service only launched single balloons from their sites and the costs would be higher. Eric recalled:

> It was a huge debate. A one-balloon system would require much more sophisticated venting and ballast systems, while a two balloon system would probably not survive a day to night transition and would not allow us to work with the National Weather Service. We argued so much, that we eventually thought, 'why not fly a one-balloon system and see.' Hence the design of flight number three.

To fly a one-balloon system, the team would need to have total control over the vertical position of the ballooncraft. To achieve this, they planned to use a combination of venting and dropping ballast. When the balloon was ascending, they would vent gas, bringing it back to the desired altitude (as measured by the on-board GPS unit). When the balloon was descending, they would drop ballast, lightening the payload, and allowing the balloon to rise. While they knew they could drop ballast easily, they didn't know whether lifting gas would actually exit the bottom of a balloon at high altitude during venting. On August 27, flight three proved a venting mechanism (and hence a one-balloon SkySite™) could work.

The next set of tests aimed at testing various ballast and venting systems. Not many of these flights went according to plan, with failures occurring due to among other things, unexpected balloon bursts, frozen venting valves, faulty GPS units, and disturbingly, a flawed parachute system, which meant the four-pound payload had a rather rapid descent to earth. In flight 9 the team began attempting longer duration flights, given that in operation, they would need the balloons to last for over 14 hours. Critically, this would require coping with day-night-day transitions, where the balloon would be heated and cooled as the sun rose and fell (and hence would rise and fall). Several flights later, success was achieved. The team was now confident that their design for ballast and venting could successfully control the balloon's altitude over long periods.

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[7] The 2-watts would be amplified by a high-gain antenna to result in a 7-watt output signal, as allowed by the FCC. User devices transmit with 1-watt of power, which also would be amplified by the high-gain antenna at the SkySite™ receiver. Also, unlike voice, the data rate from a pager to a tower is typically slower than the data rate from the tower to the pager.

On December 12, flight 15 was launched, the first test of the distance that radio signals transmitted from the ballooncraft would carry on limited power (the "link budget"). Unfortunately, this and the next were affected by venting problems. Finally however, on flight 17, the team managed to transmit a simple radio signal from the balloon at a height of 36,000 feet to the ground, over a distance of 190 miles. Three flights later, the team had made several successful transmissions from the planned altitude of 100,000 feet. The team was now confident that the link budget would work as planned.

Through the first six months of 2001, the series of test flights continued every few weeks, refining the design of the various subsystems. Then on flight 25, the team took a major step forward, testing a new liquid ballast, which replaced the sand and BB pellets that had been used up till this point. The next few flights successfully demonstrated the ability for a balloon to hover at a constant altitude, by dropping liquid ballast, and releasing air through the newly re-designed vent. On flight 29, another major upgrade was introduced, with the test of the new payload electronics. Up to this point, the payload had consisted of several standard electronic boards "cobbled together" by Eric. The new payload was a custom designed single board, which would communicate with the new ground-station equipment located at each balloon launch station.

On September 7, 2001 the team finally tested the system with actual commercial user equipment (i.e., Motorola pagers) on the ground. The successful test was followed two weeks later by a flight in which paging signals from a ballooncraft were received on the ground at a distance of 135 miles using just a ½ watt of power. Space Data was almost ready to fly!

2001: A Space Data Odyssey

As flight tests proceeded, Jerry continued to work on other fronts. The company initiated its first formal private placement of equity in November 2000, raising $1.5 million at a post-money valuation of just over $10 million, largely from Jerry's father and brother, but also with wide participation from employees, directors and advisors. This gave the team the funds they needed to increase the frequency of testing. It was then that an unexpected stroke of good luck occurred. TSR Wireless, the third largest paging company in the United States, declared bankruptcy in December 2000, freeing up the frequency spectrum space it had previously used to operate. As Eric explained:

> Our initial plan had been to sell the use of our SkySites™ much like a tower company does to existing carriers, and just use a part of carriers' spectrum for our communications needs. But suddenly the TSR spectrum was up for auction, which made us think, why not buy it? This would allow us to become a wireless company instead of a tower company, and hence capture higher returns. The down side of the TSR bankruptcy, of course, was that one less company now was available to buy our service!

Acquiring spectrum was expensive business. AT&T had originally purchased this spectrum in 1994 for $80 million, and had sold it to TSR for $20 million in 1999. How could Space Data hope to play in such a market? Fortunately, help was at hand in the form of Jerry's father once more. He created a holding company in cooperation with Space Data, set up solely to bid for the spectrum – Jerry's father contributed the money, and in return, this company would receive leasing fees from Space Data until his contribution had been repaid. The move paid off – weeks later, Space Data acquired TSR's spectrum for $3.6 million at the bankruptcy auction. The purchase was a major factor in demonstrating to the FCC and the carriers that Space Data was a serious contender in the realm of wireless communications, helping accelerate the approval process for Space Data to operate[8].

As flight tests continued through the spring, it became evident that more funding would be needed to conduct a regional systems test. So in April of 2001 Jerry and Eric began making the rounds among venture capital firms and investment banks, receiving the usual combination of initial skepticism followed by expressions of genuine interest. Most venture funds were too busy licking their wounds from the market downturn to offer any real hope of short-term funding, but the investment banks were in a better position to assist. The problem on Wall Street, however, was specific to the sector – the market for paging and messaging firms had collapsed over the past year, with most having plunged by more than 90% from their peaks (see Exhibit 14). But there was hope. One large bank told Jerry and Eric that if they met several key conditions – FCC approval, patent protection, a formal contract with the weather service, and a contract with a carrier – that a major financing round in the $15 to $50 million range was feasible. There was a catch, however. "Why" asked the bankers, "should we support your move into paging and messaging, when the real opportunity is clearly in mobile voice services? Not to mention the next wave – broadband data." (see Exhibits 15 and 16).

Undeterred, Jerry and Eric continued with flight tests throughout the summer, while Space Data grew to an organization of 18 people. To cope with the rising burn rate, a second private placement was initiated in May 2001, and closed in September with a total of $3 million raised at a post-money valuation of just under $19 million from associates of Mark Knoblach. Just as it closed, the FCC granted approval for Space Data's SkySite™ system, clearing the way for closure of the spectrum purchase from TSR. The previous week the company conducted the first successful live test of an operational SkySite™, sending wireless e-mail from a ballooncraft at 100,000 feet to an advanced messaging device over 100 miles away at the headquarters in Chandler, Arizona.

"Open the Pod Bay Doors, HAL"

By the end of September, a number of decisions began looming at Space Data. While things were going well, with the burn rate rising there was a new sense of urgency. Jerry knew that they would need additional funding – at least $10 million -- to carry out a regional paging demonstration with a major customer. To help in that effort, he had recruited his old friend, MIT and HBS classmate Dave Wu, as President. Dave's previous company, Mirror Image, had successfully raised more than $700 million in funding, and Jerry felt confident that he would be able to hit the ground running, oversee operating departments and secure the financing that Space Data needed to proceed.

Talks with the paging and messaging division of a Fortune 500 company had been going extremely well, and their engineering team had visited the Space Data headquarters several times and attended a flight test. The outlines of a contract agreement had been worked out, involving a fixed fee, plus revenue sharing for calls traveling over Space Data's network. A regional test was still needed however, to provide the concept validation needed to win the deal. Eric's attention was therefore focused on how a regional roll out should be implemented. He explained:

> The questions surround which regions and what size regions should we roll out first? We would like to stay close to home, given this will be cheaper, and logistically simpler. For example, the NOC is here in Arizona. But in this region – one with lots of desert – almost

[8] The narrowband PCS advanced messaging spectrum used for two-way paging had been underutilized and therefore problematic for the FCC. In addition, the FCC faced a federal mandate to improve service to rural communities and Indian tribal lands. Space Data's service was seen as a way to achieve this objective more economically than by using towers.

everyone lives close to the cities. Once you leave the cities, the population drops sharply, meaning that there are not as many customers for our service. By contrast, in the Northeast, the population drops off much less sharply outside cities, there are more customers available per ballooncraft and hence more profit per ballooncraft.

While Eric focused on the roll-out of paging, Jerry and Dave were reconsidering whether this was a market they should play in at all. The problem was that most potential investors were not interested in this market, especially in comparison with the rapidly evolving mobile voice sector. Two paging companies, TSR and Weblink, had already gone bankrupt, and the ones that remained didn't seem far behind. Plus Motorola was rumored to be considering pulling out of the market for consumer messaging devices. The problem was that moving to voice was not just a simple evolution of the ideas that Space Data had been working on to date. As Eric explained:

> The technical challenges are daunting – a voice signal requires a data rate up to 170 times higher than a paging signal, plus the transmission requirements are much more spectrum-intensive. You need 36Khz of spectrum to support a single voice call. We have only 100Khz. [9] It is possible to expand capacity through dividing our large coverage areas into smaller coverage "zones," each of which uses the same frequency, but this would require sophisticated directional antenna on our Ballooncraft so we could send signals only to a single zone. Even if we started work on this technology, how many voice signals should we design the payload for, and how expensive will that make it? And what if that put us over the six-pound limit? We would then have to register each launch with the FAA, and track each ballooncraft to ensure it doesn't interfere with air traffic. Finally, paging doesn't rely on real-time communication – so we can tolerate delays in delivering a message to a user. But with voice, the expectations are much higher, so there's less margin for error.

To top things off, a wild card had recently been thrown into the mix. Space Data had been approached by a major logistics company regarding the use of the ballooncraft constellation to provide telemetry -- precise, real-time tracking of shipments in transit. The resulting application would absorb a significant portion of Space Data's total network capacity, effectively ruling out paging, messaging, and voice services, at least in the short term. Although Jerry and Eric had considered telemetry on their list of target markets, the telemetry market seemed small in comparison to other opportunities. They guesstimated that it would probably generate no more than $15 million per year in revenue from the "anchor tenant" with possibly another $35 million from other customers in the same sector. The opportunity was tempting, however. Jerry reflected on the situation:

> From the beginning we had a strategic plan that was very flexible and very logical. We would start small, enter the easiest markets first (paging and messaging), learn as we grew, and enter the more challenging voice market later. Once we were well-established, we could pursue new opportunities that complemented our core business in messaging and voice, like telemetry. Now we find that our first target market is in the dumps, just as we're ready to prove ourselves with a regional test. The bankers are pushing us straight into voice, which sounds great but scares the hell out of the engineering team. And out of the blue we now have telemetry as a new opportunity, but it's certainly not the business that we dreamed about when we founded Space Data nearly five years ago. One thing is for certain – nothing will ever turn out quite the way you imagine when you're building a technology venture.

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[9] Space Data acquired 100 kiloHertz of spectrum for $3.6 million at the TSR bankruptcy auction in early 2001. An additional 1,850 kHz of narrowband PCS spectrum would come available through an FCC auction in October 2001. Approximately 1 MHz of this spectrum could be used for voice service. The FCC offered discounts on winning bids for small businesses and for firms providing service to American Indian tribal territories in remote areas.

Exhibit 1 Executive Team Bios

Jerry Knoblach

Gerald Knoblach is co-founder of the company and has served as our Chairman and CEO since our incorporation in 1997. Mr. Knoblach began concept development, research, planning and organizational work in December 1996. Mr. Knoblach earned an MBA degree from Harvard University in 1992, a master's degree in electrical engineering from the University of Minnesota in 1990, and a bachelor's degree in mechanical engineering from the Massachusetts Institute of Technology in 1985. Mr. Knoblach is a licensed professional engineer and has been awarded two patents. From 1996 to 1998, Mr. Knoblach was a program manager at CrossLink, Inc., a wireless communications equipment company. At CrossLink, he led an effort to develop a commercial communications system for the space shuttle, using a commercial satellite system, that provides connections to the Internet, voice and fax capabilities and the use of commercial hardware to enable rapid development. The system first flew in June 1998. From 1992 to 1997, Mr. Knoblach was a manager of business development and a program manager for Orbital Sciences Corporation ("Orbital"). From 1995 to 1997, he was responsible for marketing radiosondes and satellite ground stations. In 1996, he played a key role in winning a contract with the United States Air Force to develop and produce the next generation radiosondes using GPS technology. From 1994 to 1995, Mr. Knoblach served as a program manager at Orbital's subsidiary, Magellan Systems Corporation ("Magellan"), where he led the effort to develop the first hand-held, personal communicator for use with the Orbcomm© satellite network.

Eric Frische

Eric Frische is co-founder and Chief Technical Officer. Mr. Frische earned a bachelor's degree in electrical engineering from MIT in 1985. He is a licensed patent agent and has been awarded three patents . From 1989 to 1998, Mr. Frische owned and operated Applied Solutions, which was a prototyping company in Dallas, Texas. Mr. Frische was responsible for all aspects of business at Applied Solutions, from marketing to engineering and production. During his tenure, Mr. Frische developed a wide variety of prototypes in areas ranging from communications devices to toys to aides for the handicapped. Prior to Applied Solutions, Mr. Frische was a captain in the United States Air Force. While in the Air Force, Mr. Frische worked at the National Security Agency where he developed a microwave lab and research program that investigated reception of faint RF signals. Mr. Frische currently holds a technician class amateur radio license.

David Wu

David Wu serves as President and Chief Operating Officer. Mr. Wu earned a MBA from Harvard University in 1992, a master's degree in Electrical Engineering and Computer Science from MIT in 1988, and a bachelor's degree in Electrical Engineering from MIT in 1985. Prior to joining Space Data, from 1997 until 2001, Mr. Wu was a founding member of Mirror Image Internet Inc., an internet networking and content distribution company. He held various senior positions including President, COO and VP of Network Operations and Engineering, and SVP of Marketing. In his role, he was instrumental in developing and executing a business strategy that attracted over $700 million in venture investments. From 1994 to 1997, Mr. Wu was Director then VP of Marketing at VideoGuide Inc., a start up that designed and launched the first wireless interactive TV product. The product is now embedded in millions of TV sets. From 1992 to 1994, Mr. Wu worked at Intel Corporation as the original Product Marketing Manager responsible for defining and successfully bringing to market two new product lines: ProShare Video Conferencing and the new video multimedia product line. From 1986 to 1990, Mr. Wu worked as an engineer developing various software and digital signal processing technologies at General Scanning Inc. and at Analog Devices.

Exhibit 2 Key Director & Advisor Bios

Randy Hoffman – Board Member

Randy Hoffman is a certified public accountant and earned an MBA from Harvard University in 1980. Mr. Hoffman co-founded Magellan in 1987, which produced the world's first hand-held GPS receiver, and served as its president and chief executive officer from 1987 to 1997. During this time, Magellan was the first company to deliver a consumer GPS receiver for less than $100. Mr. Hoffman serves on the board of directors of two other companies, beOutdoors.com and Escend Technologies.

David Jones – Board Member

David Jones earned a bachelor's degree and a law degree from the University of Minnesota. Since 1994, Mr. Jones has served as general counsel for Hubbard Broadcasting, Inc. From 1994 to 1999 he also served as senior vice president of United States Satellite Broadcasting ("USSB") until its merger with DirectTV in May 1999. At Hubbard, Mr. Jones is responsible for overseeing corporate legal affairs, including regulatory compliance with the FCC and Securities Exchange Commission.

James Knoblach – Board Member

James Knoblach earned an MBA degree from Harvard University in 1981, a master's degree in American government from Georgetown University in 1987 and a bachelor's degree in economics from St. John's University in 1979. Since 1994, Mr. Knoblach has served as a representative to the State of Minnesota legislature. Mr. Knoblach is the president of North Star Resources, a venture capital firm, and sits on the board of Advanced UroSciences and Harbinger Medical.

Eric Schimmel – Board Member

Eric Schimmel earned degrees in electrical engineering and business administration from Northwestern University. In 1999 he retired as vice-president of the Telecommunications Industry Association ("TIA") where he was responsible for the administration of policy and technical activities of the wireless communications division. Mr. Schimmel was appointed by the U.S. State Department to head the U.S. delegation to Working Party 8A of the International Telecommunications Union, which oversees international regulation of terrestrial mobile services including paging and cellular services.

Bruce Bollerman – Advisor

Bruce Bollerman was the chief engineer for the original Space Data Corporation from 1963 until his retirement in 1996. Mr. Bollerman lead the development of small unguided fixed fin sounding rockets for NASA and US Air Force customers, developed radiosondes for the NWS and the US Air Force, developed ground tracking antenna systems, and developed large inertially guided suborbital and orbital launch vehicles. During his tenure, the company delivered approximately 30,000 radiosondes per year to the NWS during the late 1980s.

Frank Schmidlin – Advisor

Frank Schmidlin is a meteorologist at the NASA Wallops Island Flight Facility. He is widely acknowledged as the country's leading expert on radiosondes and upper air meteorology, and he invented the modern meteorological rocket. Mr. Schmidlin is a member of the U.S. delegation to the World Meteorological Organization, which is the United Nations organization that oversees the world's radiosonde launch network.

Exhibit 3 Space Data Corporation Organization Chart as of November 2001

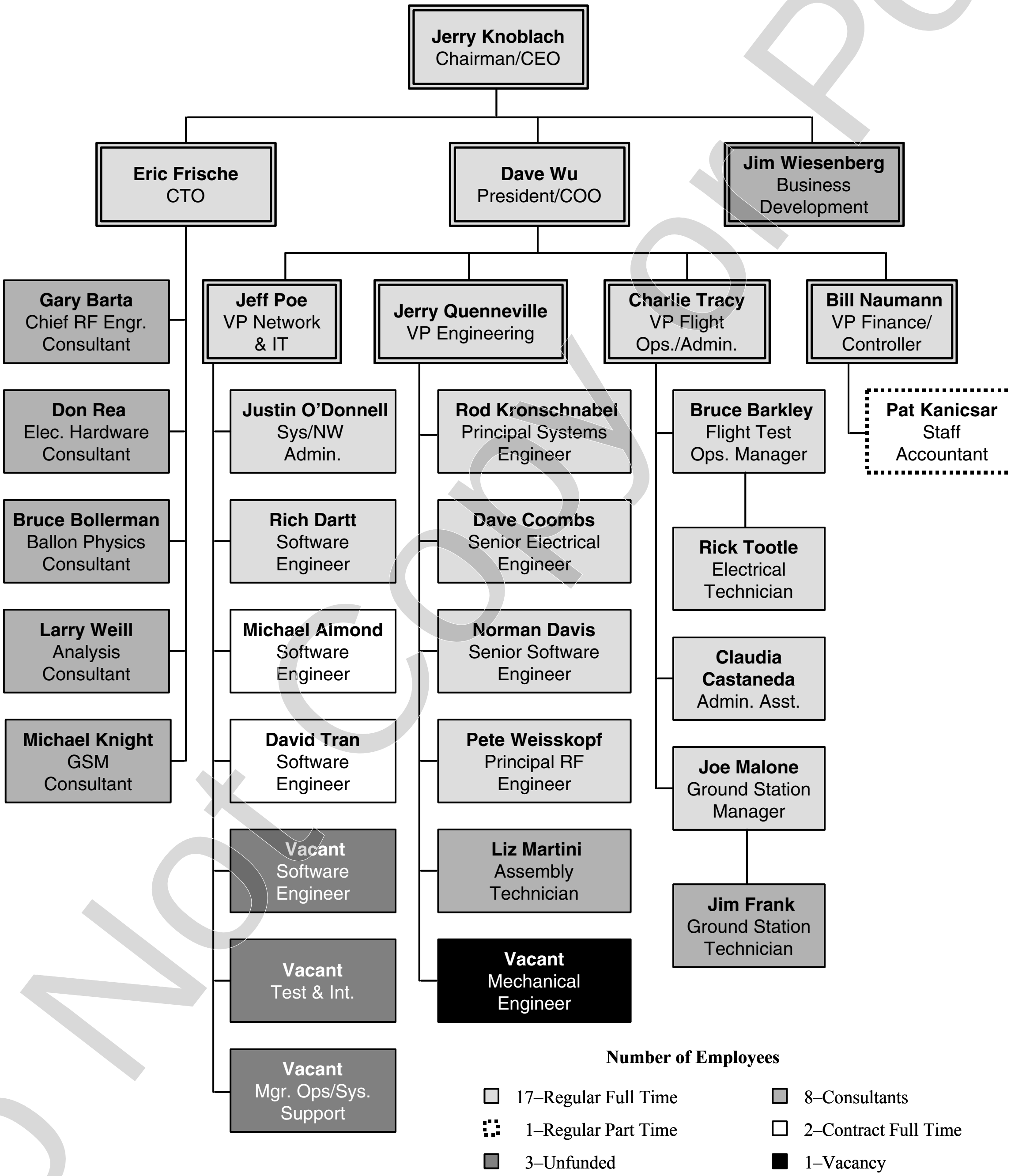

Exhibit 4 Tower-Based Wireless Coverage of the United States

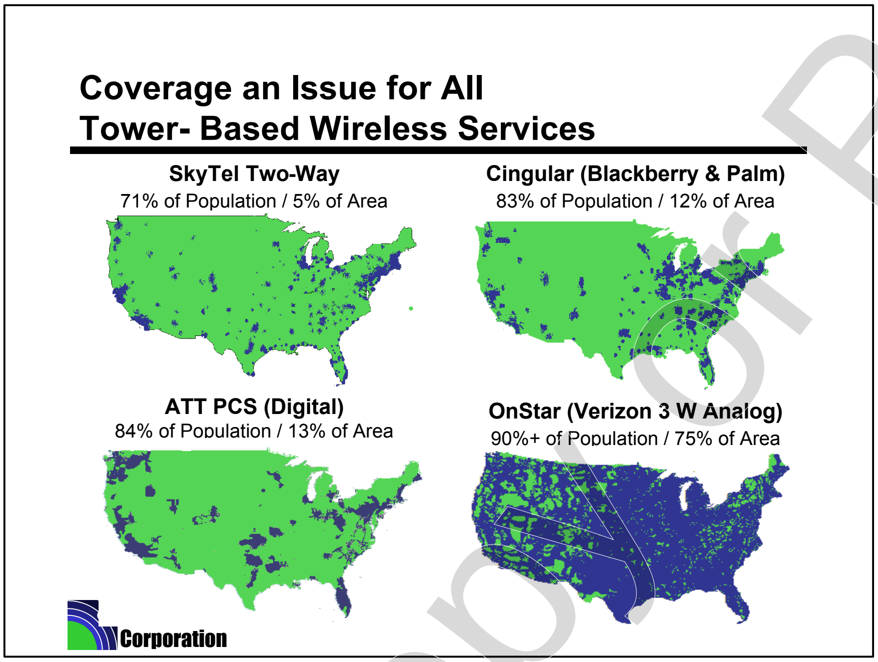

Exhibit 5 Space Data Basic Market Assumptions

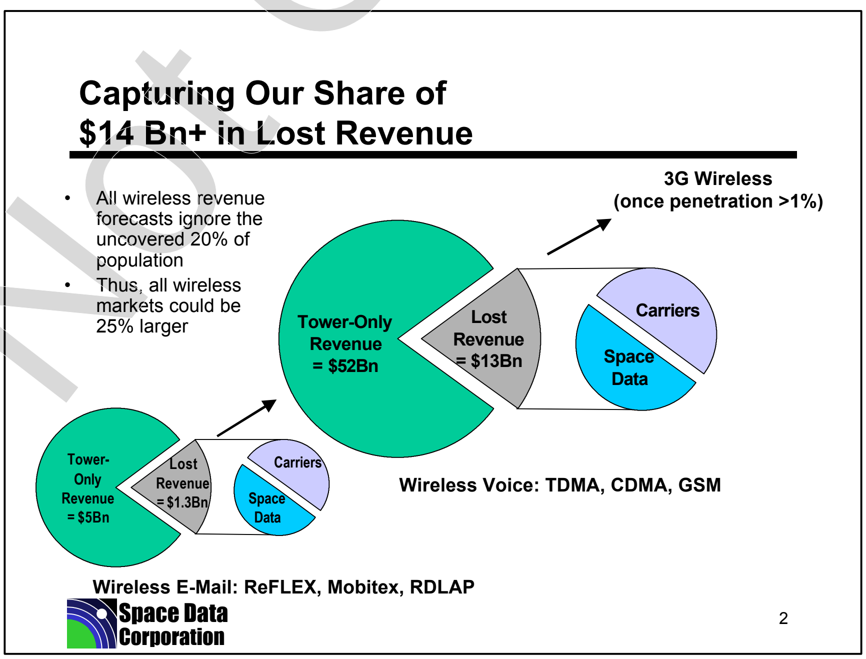

Exhibit 6 Satellites versus Ballooncraft

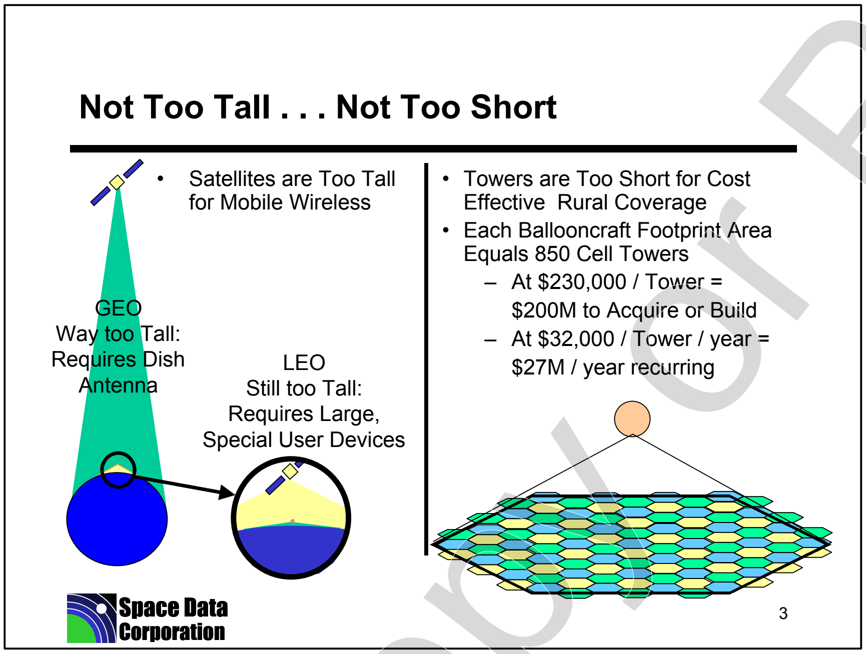

Exhibit 7 Economics – Messaging via Space Data, Towers, & Satellites

Short Messaging Comparative Economics

- Our solution provides a superior cost structure in sparsest areas
  - 56MM pops (20% of total pops) with an average 20 pops/sq.mi.

	Space Data Ballooncraft	Towers	LEO Satellite
Coverage Radius (miles)	**180**	**15**	**1,500**
Total Non-Recuring	**$100,000**	**$230,000**	**$36,000,000**
Recurring Site Cost / Mo	$300	NA	NA
Launches / Mo	61	NA	NA
Total Recurring Costs / Mo	**$18,250**	**$2,667**	**$185,000**
Sparse Pops Covered	2,035,752	14,137	56,000,000
Penetration	1.0%	1.0%	1.0%
Subscribers	20,358	141	560,000
Monthly Cost / Covered Pop	**$0.01**	**$0.46**	**$0.01**
Monthly Cost / Subscriber	**$0.98**	**$45.98**	**$1.40**

Space Data Corporation

4

Exhibit 8 Space Data Ballooncraft Payload Diagram

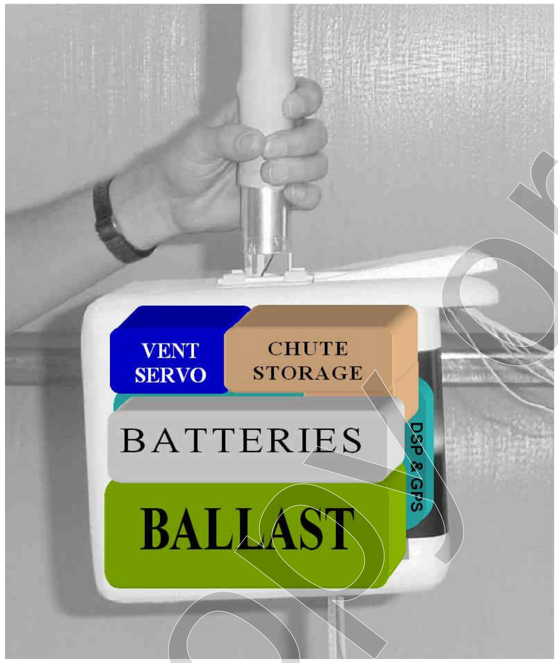

Exhibit 9 Space Data Ballooncraft In-Flight Diagram

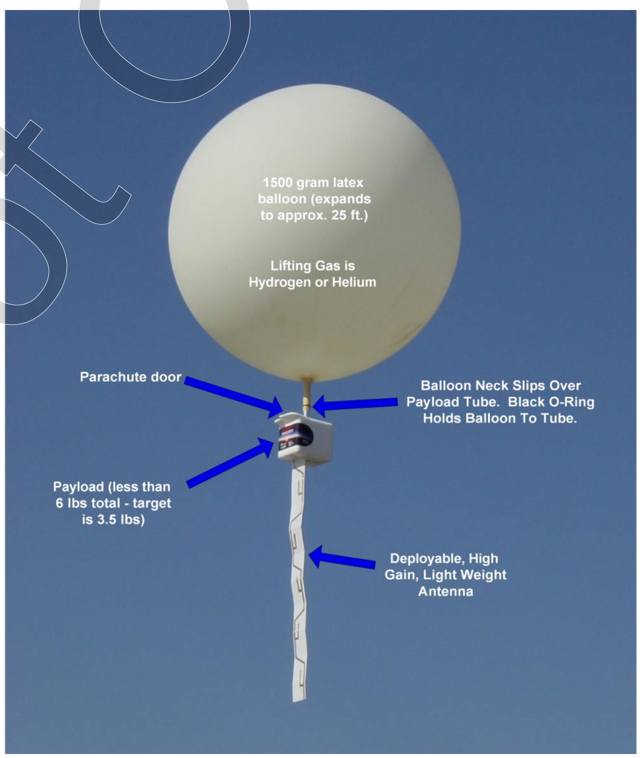

Exhibit 10 Space Data Payload Design with GPS Boom & Vent Opening

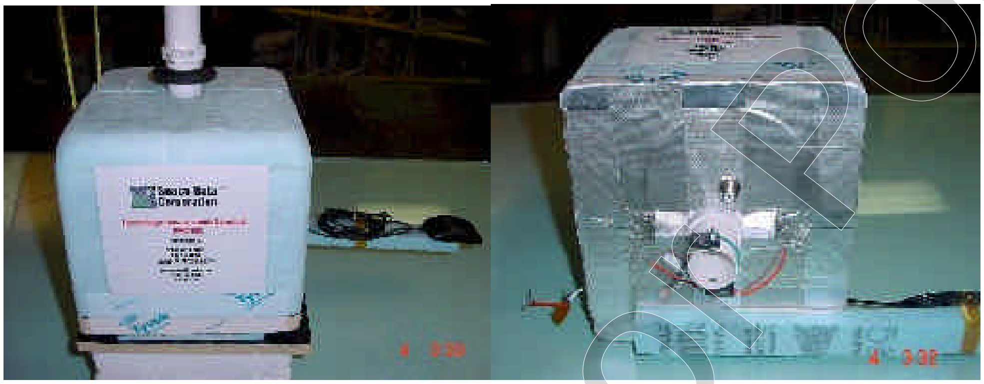

Exhibit 11 Ballooncraft Launch

Exhibit 12 View from Ballooncraft During Ascent / At Altitude

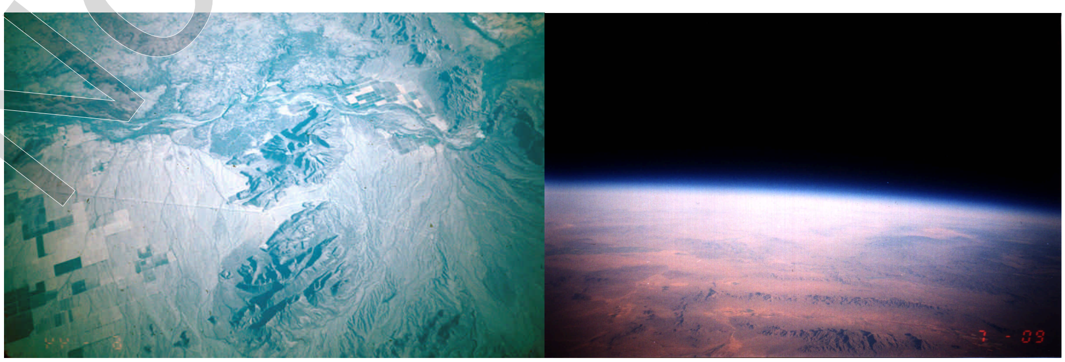

Exhibit 13 Space Data Flight Test History

1 *6/28/00* *11.5 hr float at 55 - 87Kft to Desert Center, CA with two balloon system*

This balloon flight, to a large extent, proved that the balloon could survive in the environment and was considered an amazing success. Many people we had talked to said that the balloon would oxidize quickly, become brittle and burst. Ozone at this altitude might be a strong source of oxygen for oxidation. This flight used two balloons. One would lift the payload to altitude and burst, while the other provided enough lift to maintain float after reaching altitude. One balloon vs two balloons was a major issue within the company at the time. The issue caused a lot of consternation and took until flight 3 to be resolved. Many things were learned from this flight such as how to more accurately estimate when a balloon would burst. There were also large altitude variations at float because the balloon altitude could not be controlled with the two balloon system. […] The parachute color was changed from black after this flight to bright colors after an unsuccessful attempt to locate the landed payload from a private airplane. The desert terrain and color made it impossible to locate the payload. The payload was found over a year later and returned by an off duty fireman who was four-wheeling in the desert.

2 *7/26/00* *Premature Balloon burst ~ 2 hours*

This was to be a repeat of flight number one. An unexplained balloon burst occurred approximately 1 hour into the climb. The balloons were manufactured by Scientific Sales. See flight 4.

3 *8/27/00 Terminal Vent (Single balloon system) Demonstrated*

This was also a very important flight as it proved that a single balloon system would work. This was important for a number of reasons including overall system cost, reliability, and because the National Weather Service (NWS) could not launch a two balloon system from their facilities. The question revolved around whether lighter-than-air gas (hydrogen or helium) would exit the bottom nozzle of a large rubber balloon when the majority of the force was upward. The thought was that the balloon experienced some loss of flexibility in the cold at altitude and would not have the pressure to force the lifting gas down and out the small nozzle. The debate was quite heated. Balloons left on the ceiling did not loose all of their gas even with the downward facing nozzle open. This flight's sole purpose was to open a vent covering the nozzle at 60,000 feet and see how soon the balloon would stop ascending and come down. One of our scientific advisors had estimated within 7,000 feet or less, others felt it would not turn around at all. The slallooncraft turned around within 2,500 feet. All flights since have been single balloon flights. The ballooncraft was recovered.

This flight started a new series of payloads in which the shape became more compact, the vent tube was part of the payload structure, and all components of the payload were located together for ease of launch. A balloon burst mechanism was also included, but was not needed as the ballooncraft descended following the venting. Later ground testing showed that this method of bursting a balloon (physically poking the balloon with a sharp object) would only work when the balloon material was tight as it would be at high altitudes. This meant the method could not be used in production, as the payload may need to be brought down at low altitudes as well. The GPS antenna had to be moved out on a 1-foot boom because it was receiving interference from the payload processor. Attempts were made to try to shield the processor without success, so the boom was used.

4 *9/19/00* *Premature Balloon Burst at 60Kft*

This flight was to demonstrate a ballast test. Ballast was to be a series of BBs that could be individually dropped (over the desert). BBs would not be used in production. Damage tests were done at the BBs terminal velocity. Sand was also used as additional ballast. Before ballast could be tested, the balloon burst. There are three primary latex balloon manufacturers that supply to the US market. These are Kaysam (US), Scientific Sales (US) and Totex (Japan). After several failures and visual examinations of the balloons (after flight 4), thin spots were found in the balloons ordered from Scientific Sales. We were told by Scientific Sales that these balloons were from Totex. After talking to the Totex representative, we were advised that Scientific Sales had bought the old molds from Totex and were selling the balloons as Totex. We have never tried to confirm this, but we have stayed away from Scientific Sales balloons, as their flaws are quite visible.Allooncraft was recovered.

5 9/21/00 Slow vent caused balloon to burst at 115Kft - lost GPS on descent

This flight was also designed to be a ballast test. Before ballast could be tested, the vent failed in a closed position and the balloon rose to burst. The vent design from this flight up until flight 31 used a memory metal to actuate the vent. This actuator shrunk when heated by passing a current through the memory metal wire. This shrinkage was used to open and close the vent. The memory metal wire was placed inside the vent tube for ease of design. Unfortunately, the flow of the lifting gas through the tube quickly cooled the memory metal and the vent partially closed. The vent could not release lifting gas fast enough in the colder temperatures. GPS data from the payload was lost at too high of an altitude to recover the payload (they drift considerably on the way down).

6 10/4/00 Achieved float after vent

This flight was to be a ballast test. The vent wire was protected from the cold in a sheath, and the vent worked well. Before ballast could be released, the balloon burst after 2 hours and the parachute did not deploy from the parachute tube. The payload landed a golf course and was discovered by the greenskeeper. Since the parachute had not deployed, the impact destroyed the payload and most of its components. The payload was recovered in pieces. A completely reliable, easy to launch parachute system had not yet been found. The parachute system was eventually modified to work much more reliably, although the system is not such that it can be produced and shipped in quantity. Alternate designs are slated for testing around flight 36. Telemetry was lost at 17k feet due to weak signal. Unsure of reason.

7 10/8/00 Achieved float after vent - lost GPS after 4 hours at midnight GMT

This flight was also to be a ballast test. GPS (not telemetry) was lost at exactly midnight GMT. Although ballast was dropped, there was no GPS position feedback to verify if it worked. The payload could not be recovered. Because of the exact time GPS was lost, it was suspected that the Garmin GPS units had a software problem. Because of this flight, circuitry and software were added that allowed the GPS to be hard or soft reset from the ground. In addition, a separately powered recovery beacon was added to the next payload.

8 10/13/00 Premature power failure at 10Kft

Faulty wiring was the probable cause. This payload had the GPS antenna on the payload as opposed to a boom. The RF interference problem from the processor had been solved by changing the operating frequency of the processor. A recovery beacon was placed on this payload, but was too distant to pick up and the payload was not recovered.

9 10/21/00 19 hour duration flight, achieved stable float at 116Kft, night / day transition

The goal of this flight was to test longer flight times on the balloon itself. The flight was successful for a number of reasons. This flight successfully increased our long duration flight time to 19 hours. Float at higher altitudes was achieved and a night to day transition was accomplished. During a night to day transition, the balloon must be carefully vented to prevent burst from rising too high when sunlight hits the balloon and warms it. Although the current operational altitude of the ballooncraft is 100,000 feet, additional altitude can dramatically increase the coverage circle. A ballooncraft can be raised to help fill a nearby gap, for example. Ballast drop was attempted, but did not function due to the ballast control wires coming loose. The entire payload was shielded to provide additional interference reduction for the external GPS antenna. The payload was recovered.

10 10/27/00 12 hour duration terminated by 75 Kft rise to burst at sunrise

The goal was to achieve a night to day transition and perform further vent and ballast tests. At sunrise the ballooncraft ascended from 45,000 feet to over 120,000 feet due exclusively to the effect of the sun's rays hitting the balloon and causing a significant rate of climb. This test conclusively proved the significant effect the sun could have on sustaining long-duration flights. Ballast release was still unsuccessful due to insufficient electrical current. Vent test was successfully completed. The payload descent speed seen in the telemetry indicated the parachute did not deploy. Payload not recovered and assumed to be destroyed.

11 11/8/00 11 hour duration, first ballast drop, night / day transition

This flight was scheduled as an additional night to day transition and a ballast test. The ballast system worked properly and the data was collected to determine how much ballast would be necessary in production, although these numbers would have to be refined over time.

12 11/10/00 22+ Hour duration flight, 95k ft and 105k ft float, first ground video

Successful extended duration flight of 22+ hours. First video of ballooncraft from the ground. This was an important flight because the flight duration approached 26 hours. The flight terminated due to limited battery life and lack of ballast, not because of balloon burst. The NWS launches every 12 hours and the ballooncraft takes 2 hours to reach altitude, therefore the ballooncraft life must be in increments of 12 hours with 2 hours added for the initial rise to altitude. That gives 14, 26, 38, etc., hours as the optimum life for the ballooncraft. In general, the maximum life required would be 3 days because in that time a ballooncraft launched from almost anywhere in the US would float out of the country and would no longer be usable.

13 11/21/00 Premature balloon burst at 88KFt – valve vented too slowly

Vent sluggish, friction in the mechanism suspected. We plan to use low temp grease on the mechanism in future flights.

14 11/27/00 Achieved first day / night ballast drop - First remote launch

When the ballooncraft transitions from the warmth of the sun during daylight to night, the ballooncraft falls as the lifting gas cools. There is enough change in lift that the ballooncraft descends all the way to the ground. Ballast must be dropped to offset this loss of lift. Typically, it takes approximately 9 to 15% of the total payload and balloon weight to offset each day to night transition. This was successfully done in this test. The flight took approximately 9.5 hours.

15 12/12/00 Link Budget Flight 1 - Vent failed after leveling off – balloon burst at sunrise

A Motorola Createalink 2XT (a ReFLEX telemetry unit) with a patch antenna was hung 75 feet below the main payload on a cord. The Createalink was set to transmit a pseudo random bit pattern that would be measured for bit error rate on the ground to help verify the link budget. The vent leveled the payload off at altitude, but later failed and sunrise caused the balloon to rise. The payload was recovered and a new vent was designed for the next flight. Before each of the link budget tests, string tests were done on the payload to test the electronics and RF in a controlled environment a few hundred feet above the ground. In addition, all payloads were tested in the altitude chamber to test for thermal concerns in a near vacuum environment.

16 12/15/00 Link Budget Flight 2 - New high flow vent design – over vented during ascent

This was a repeat of flight 15 with a new vent design. The memory metal wire was moved outside of the vent tube where it could be kept warmer. The vent design worked so well that it was over vented and the payload descended before it could be stopped. This design was used in subsequent flights with more care being taken by the ballooncraft controller on the ground. The payload was recovered although it hit hard and sustained some damage.

17 12/20/00 Link budget w/omni 190 mi/36KFt/0.65 deg elev. angle with error free data

This was a very successful link budget flight (as described in flight 15) with the new vent design from flight 16. This flight was the first step in answering the second crucial question mentioned in flight 1; Will the on paper link budget completed in the feasibility study prove to be correct? Can we really communicate with a 2 way email device (2 way pager) at 284 km with 2 watts of transmit power when ground based towers can typically only reach 10 - 15km with 350 watts of transmit power? This test used the proper modulation, power, and frequencies and showed that with a non-optimal antenna the link budget could reach from a ballooncraft 190 miles away even with a low ballooncraft altitude. The link budget tests would eventually need to progress to using actual advanced messaging user equipment on the ground, a high gain antenna on the ballooncraft, and a higher ballooncraft altitude, but the results seemed to verify many of the feasibility study assumptions. This had been a remote launch downwind of the receivers in the office to try to maximize the distance of the receivers from the ballooncraft as quickly as possible. This is because winds at altitude were forecast to be light that time of year.

18 1/10/01 Link Budget Flight 4 - high gain antenna – telemetry radio failed at 25 Kft

This flight had the addition of a specially designed high gain antenna attached to the Createalink. Micropulse of California had designed and built the prototype high gain, lightweight, antenna specifically to Space Data's requirements. Two were built initially. Unfortunately, the main payload telemetry failed so the results could not be correlated to distance. The chase vehicle was within approximately one mile of recovering the payload by triangulating the signals from the Createalink and the new antenna, when the battery life ran out. The payload was not recovered.

19 2/16/01 Link Budget Flight 5 – limited information gained

A repeat of flight 17 was attempted. An error in filling the balloon meant that the balloon did not have enough lift to obtain float altitude. Because of this, a more rigorous launch procedure was initiated. The ballooncraft was recovered.

20 3/14/01 Link Budget Flight 6 – 200 mi/92KFt/1 deg elev. angle with error free data

This flight was very successful. The link budget test (same setup as flight 17) brought the link budget to an even greater range of 200 miles due to the increase in altitude. This is important, as the desired range from the ballooncraft is 176 miles. The flight was eventful in other ways as well. The ballooncraft slowly lost gas after float from a leak in the balloon, neck assembly, or vent (unknown). The ballooncraft was vented to bring it down at the end of the mission. When the ballooncraft touched the ground, apparently in the high surface winds, the lower payload (the Createalink payload) caught on the ground, the string between the lower payload and the main payload broke and the ballooncraft rose again due to the loss of the lower payload weight. The ballooncraft rose again to 95,000 feet. Unfortunately the adventures of this chase ended when the chase vehicle broke down in Midland Texas and the payload was lost. The main payload was later found by a farmer in his field and returned by mail .

21 3/21/01 Link Budget Flight 7 - Confirmed Flight 20 link budget results

Repeat of flight 20. Leveled off at 100,000 feet. Some loss of altitude occurred due most probably to loss of lifting gas from a leak in the vent seal. However, the system checked out okay before launch. The link budget data was confirmed, but not to the same distance as flight 20. Later in the flight, the telemetry link was lost because the chase vehicle had a flat tire and the replacement vehicle was unable to catch up to the ballooncraft. The confirmed link budget data became limited to the farthest the chase vehicle could continue to obtain telemetry data. Without telemetry, the ballooncraft location is unknown. The payload was not recovered.

22 5/24/01 Altitude Burst test, high altitude photos – leaking vent prevented sunrise climb

This test was to determine at what altitude a 2,000 gram balloon would burst, and to obtain high altitude photos from an on board film based camera. A $29 instant camera was modified and used for the photos. The photos were successfully taken under ground control. One of them has become the primary photo used on Space Data's literature. The vent, even with the modifications to the seal against the neck of the tube, leaked. This prevented a controlled climb at sunrise to capture the maximum burst altitude of the balloon under a known weight.

23 6/12/01 Balloon Altitude Burst test – early burst

This test was a repeat of flight 22, this time using a 1,500 gram balloon. The goal was to allow the balloon to rise to burst after it had leveled off at 100,000 feet, vented down to a lower altitude and then allowed to rise with the sunrise to burst. The vent did not open wide enough and the balloon rose to burst. These tests were performed to determine the maximum float altitude for the balloon after leveling off and experiencing some fluctuations in altitude. This test only gave us information as to the ballooncraft's maximum altitude without fluctuations [and] would have to be repeated.

24 6/14/01 Balloon altitude burst test, downward pointing camera installed, burst above 109KFt

This was a repeat of flight 23 with a change in the vent seal from a foam to a silicone flapper. The flight data was used to determine the effective operating altitude for 1,500 gram balloons. This data can also be extrapolated for use with other size balloons. In the modified vent design, an improved center pressure point on the vent itself allowed for a more even pressure distribution across the seal. This seal worked effectively and the new seal design has been used on all subsequent flights. The photos were successfully taken under ground control and showed moderate resolution even from an inexpensive camera. These photos, like the photos from flight 22, were used in presentations to investors, potential customers, etc. The payload was recovered.

25 6/19/01 Successful fully controlled hover, new liquid ballast test, and internal photos

A liquid ballast system was tested on this flight. The liquid ballast is metered out by an electrical valve for a length of time commanded from the ground. Eventually, the on board processor will control both the ballasting and venting to maintain the proper altitude range. Environmentally benign fluid that stays liquid to –80C is used as the liquid ballast. The sealed ballast tank is initially at 1 atmosphere absolute so that it is effectively unpressurized on the ground. As the ballooncraft rises, the pressure outside the tank falls creating a pressure differential across the ballast release valve. The altitude effectively pressurizes the tank as it rises allowing the ballast to be released much quicker even when the liquid becomes more viscous due to the low temperatures. A sealed ballast tank makes shipping the payloads safer. The liquid ballast system is also safer in potential impacts than solid ballast . Liquid ballast can be metered in as small as increments as desired.

This flight performed a series of various sized ballast drops and leveled off after each to determine the effect on altitude. Following this, a series of vents were performed at different altitudes to determine their effect on altitude. The payload control worked well. The flight was successful. After the end of the mission, the payload was terminally vented and the payload initially fell at a normal rate. Then the payload unexpectedly slowed its fall near 60,000 feet and hovered for nearly 4 hours. No ballast remained and venting was ineffective. After 4 hours, the payload resumed its fall and was recovered. It is now believed (after flight 34) that the balloon was over distended and became effectively a loose bag preventing additional venting. This will later be seen in flight 34 when an over distended balloon was recovered intact. In operational flights, flight termination will be accomplished by releasing the payload from the balloon. Payload was recovered.

The amount of liquid ballast was supposed to be confirmed by an internally mounted camera. The camera experienced too cold temperatures and the film did not expose. The camera will be better insulated next flight.

26 6/26/01 Hover and ballast test – GPS failure at 57,000 feet

The payload still consists of multiple boards connected with a multitude of wires. It was discovered after recovery of the payload that the GPS output signal wire had come loose within the connector. This was a night launch. Without GPS position in the telemetry, the location of the payload is not known. As soon as the GPS was lost, the payload was commanded to terminal vent. This payload was followed in the dark by signal gain tracking by moving the antenna until the signal is the strongest and driving the chase vehicle toward the estimated landing site. The payload was recovered.

27 6/27/01 Hover and ballast test repeat

This was a successful repeat of flight 25. One of SkyTel's engineers accompanied the Space Data team on the chase. The amount of liquid ballast was confirmed by recovering a camera mounted inside the payload that monitored both the opening of the vent and the liquid ballast level remaining. Additional camera insulation allowed the film to be adequately exposed.

28 7/17/01 First video of payload ascent and descent

An on board video camera recorded various portions of the ballooncraft flight. The video was fairly short because during ascent, the heavy payload rocked a lot causing the line holding the radiosonde below to sweep over the vent, tangling it and preventing it from opening. As a result, balloon rose to burst. The video camera obtained excellent footage of the rise of the payload. The payload and video camera were recovered for future flights.

29 7/19/01 New payload electronics and ground station tested

This flight represented the transition between the previous generation of payload electronics and the next. In this test, the old payload electronics, used continuously since flight 1, carried the new SkySite™ to altitude and hover to test the basic functioning of the new payload electronics in the environment. The new radio link to the new ground station (also under development) was tested successfully as well as the transfer and display of ballooncraft GPS position and status data on the new ground station computers. The old payload electronics were a combination of off the shelf and custom boards and the multiple interfaces between them. The new payload electronics incorporated all of the functions of the old payload electronics into one DSP based custom board and one GPS daughter board. The unreliable wiring interfaces between the various boards were removed. This has the potential of dramatically increasing reliability. The electronics are now all Space Data custom devices and designed specifically for our mission on our frequencies. The new ground station is necessary to talk to the custom electronics onboard the ballooncraft.

A 2000 gram Totex balloon was used for this flight because the regular Kaysam balloons were late in delivery from the factory. The balloon burst in level flight for unknown reasons. The probable cause was related to the large weight of flying two full payloads on the same ballooncraft. The flight was successful and the payload was recovered.

30 7/25/01 Video flight - Videoed NWS Radiosonde release & Payload Stability at 100,000 feet

This flight had multiple goals all of which were achieved. The primary goal was to verify the general consensus in the industry that a ballooncraft is very stable when leveled off at altitude. This is extremely important to the design of the high gain payload antenna. If the antenna rocks due to balloon movement, the antenna pattern must be adjusted to a less efficient pattern to nullify the effects. The flight results show that the payload and antenna are both extremely stable, with no rocking visible at float. The flight also took video of the antenna deploying from folded up to fully deployed. This flight towed a NWS radiosonde 75 feet below. The down-looking video camera recorded the radiosonde on the flight up in order to show the NWS how their radiosondes oscillate during climb. Previously, there had been no record of how the radiosondes acted on the ascent. In a normal NWS launch, the mission of the NWS radiosonde is complete after it rises to 100,000 feet. In operation, Space Data will use the radiosonde as ballast to offset the loss of heat during a day to night transition. Video was taken during the release of the NWS radiosonde from 100,000 feet for two reasons. It showed how much the antenna rocked due to the instantaneous release of a sizable amount of weight. The antenna did rock slightly, this will have to be addressed. Secondly, it showed how a small parachute released in low atmosphere acts on descent. This information is used to determine when and how the parachute should be deployed after balloon burst or release. The payload was recovered. The video has become an important selling item for new employees and investors.

31 8/29/01 Paging Technical Committee flight demonstration

Minimal payload. The mission was to show the launch, control, and tracking of the ballooncraft for Space Data's primary customers. Payload recovered.

32 8/31/01 Proprietary payload—Successful Vent control verification

The new payload electronics were flown successfully without the older payload. All payload commands were through the new payload electronics using the new ground station to payload protocol. This is effectively a complete upgrade to the entire payload and RF electronics to a level that is very comparable to the eventual production ballooncraft. A new, more production oriented vent design was also tested successfully. The new design is based on a servo from model airplanes. A premature balloon burst occurred at 88,000 feet. The cause is unknown. The payload was very heavy, and like flight 29, could very well have been the cause of the premature burst. An effort to significantly reduce the weight will be accomplished before the next flight. No ballast system was on the payload. As the payload descended after balloon burst, GPS was lost at 77,000 feet. The payload was tracked by the same gain tracking method used in flight 26. When the parachute attached to the payload neck opened at a lower altitude, the heavier payload pulled the neck off of the payload and the payload fell without a parachute. The damaged payload was recovered. The neck attachment was strengthened for future flights.

33 9/7/01 1st 1-Way page completed from 100k ft and 100 miles

This very successful test accomplished a series of one-way pages to commercial user equipment! This is the first test actually using the advanced messaging units themselves! Some RF problems regarding interference between the receive and transmit antennas will be addressed before the next launch.

34 9/28/01 2nd 1-Way page (100k ft & 135 miles)

Continued success with a one way page going even further (135 miles) on only ½ watt of power. The operational goal is 176 miles. The ½ watt was a limitation of the current RF amplifier onboard the ballooncraft. The FCC has allowed Space Data to transmit up to 47 watts. A problem to be addressed involved communications between the ground station and the ballooncraft being lost periodically. The ballooncraft electronics had to auto reset to reacquire communications. When communications were reestablished, the GPS system did not reset. A command had to be issued to the payload to reset the GPS. This worked. The payload came down on the balloon. The balloon appeared over distended. This will be investigated as to its cause and possible effect on operations. This flight was a remote launch.

Exhibit 14 Paging, Tower, and Mobile Voice Company Market and Financial Performance

	Stock price: 52-wk high (01/09/02)	Stock price as of 09/28/01	FY00 Revenue ($ millions)	FY00 Net Profit ($ millions)
PAGING				
Arch Wireless (ARCH)	$2.31	$0.02	$851	($310)
WebLink Wireless (WLNKA)	$3.00	$0.04	$290	($118)
Metrocall (MCLLQ)	$1.44	$0.09	$562	($215)
TOWERS				
American Tower Corporation (AMT)	$41.50	$13.89	$735	($195)
Crown Castle International (CCI)	$30.13	$9.00	$649	($205)
SpectraSite Holdings (SITE)	$18.44	$2.41	$347	($158)
Pinnacle Holdings (BIGT)	$12.69	$0.39	$176	($124)
MOBILE VOICE				
Sprint PCS (PCS)	$33.25	$26.29	$6,341	($1,871)
AT&T Wireless (AWE)	$27.30	$14.94	$10,448	$658
Nextel (NXTL)	$38.63	$8.64	$5,714	($815)
Western Wireless (WWCA)	$49.75	$33.78	$835	$65
DIVERSIFIED TELECOMM				
MCI/Worldcom [SkyTel] (MCI)	$23.50	$15.04	$39,090	$4,153
Verizon [Verizon Wireless] (VZ)	$57.40	$54.11	$64,707	$11,797

Exhibit 15 Paging and Messaging Market: Subscribers and Revenues (U.S.) 1998-2007 -- Frost & Sullivan, "Analysis of the Narrowband PCS Market in the U.S." September 1998 and "U.S. Mobile Messaging Market, Paging and Advanced Messaging Market" December 2001

	1998 Forecast One-Way Paging & Two-Way Messaging (dedicated devices)		2001 Forecast One-Way Paging & Two-Way Messaging (dedicated devices)	
Year	**Subscribers (millions)**	**Revenues* ($ billions)**	**Subscribers (millions)**	**Revenues ($ billions)**
1998	50.0 (e)	5.0	46.2	4.7
1999	60.0 (e)	6.0	46.0	4.7
2000	69.0 (e)	6.9	42.2	4.1
2001 (e)	80.0	8.0	38.3	3.4
2002 (e)	84.0	8.4	32.2	2.5
2003 (e)	90.0	9.0	25.3	1.9
2004 (e)	96.0	9.6	16.2	1.1
2005 (e)	108.0	10.8	6.2	0.4
2006 (e)	114.0	11.4	2.7	0.2
2007 (e)	120.0	12.0	1.6	0.1

* NOTE: Revenue estimates are calculated based upon $100 per subscriber per annum assumption, not included in original 1998 Frost & Sullivan forecast, but consistent with prices circa 1998.

Exhibit 16 The Cellular Telecommunications and Internet Association's Twelve-Month Wireless Industry Survey Results 1992-2001 (U.S. cellular, ESMR, and PCS voice services)

Year	Subscribers (millions)	Subscriber Growth Rate (%)	Revenues ($ billions)	Revenue Growth Rate (%)
1992	8.9	---	6.7	---
1993	13.1	47%	9.0	34%
1994	19.3	47%	12.6	40%
1995	28.2	46%	16.5	31%
1996	38.2	35%	21.5	30%
1997	48.7	27%	25.6	19%
1998	60.8	25%	29.6	16%
1999	76.3	25%	37.2	26%
2000	97.0	27%	45.3	22%
2001	118.4	22%	58.7	30%