# PRT Activism: Strategies & Attitudes Towards Conventional Transit

By Nathan Koren
24 May 2008

*"There is nothing more difficult to plan, more doubtful of success nor more dangerous to manage than the creation of a new system. For the initiator has the enmity of all who profit by the preservation of the old institution and merely lukewarm defenders in those who would gain by the new one"*

– *Niccoló Machiavelli, The Prince*

*"Strategy without tactics is the slowest route to victory.*
*Tactics without strategy is the noise before defeat."*

*– Sun Tzu, The Art of War*

## *Introduction*

Until very recently, Personal Rapid Transit (PRT) companies had amassed a decades-long record of failure. It wasn't technological failure: the basic concept had been proven many times over, with the first full-scale integrated system demonstrated in 1968. The failure was institutional. PRT companies were typically unable to attract investment, and even when they occasionally did so, never successfully brought their products to market.

This is beginning to change: London's Heathrow airport is building what will become the world's first PRT system, and plans are moving forward to build other systems in the UK, Sweden, the UAE, and elsewhere. PRT has found a toe-hold in the market, but its position is still precarious. The next few years will determine whether the industry finally achieves sufficient momentum and mass to overcome the numerous obstacles in its path. It must face not only the usual challenges encountered by any disruptive technology, but also the institutional and cultural artifacts created by its long and difficult legacy.

During the past four decades, small but vocal groups of people – seeing the tremendous benefits that PRT would offer – have become passionate advocates for PRT. Some have tried to influence the public sphere, writing letters to the editor and pitching it to their representatives, to no avail. Others, frustrated by the conservatism of the public sector, have started up a multitude of entrepreneurial private PRT ventures. Most of these ventures sank without a trace, while a few managed to turn their failures into public spectacles. Many such ventures are still idling along, perpetually short of capital.

From the 1980s until the present, this has primarily been an American phenomenon. Which makes it somewhat ironic that today's leading PRT vendors – well-funded, well-managed, atypically strategically and politically astute – are based in Europe. In America, a handful of PRT companies have also begun making significant strides in this direction, but they remain short of funding and at least a few years behind the competition. These firms are somewhat handicapped by the fact that America is generally less interested in public transport, whether innovative or not – but they are also encumbered by the history of failed entrepreneurialism and misdirected activism, which has stigmatized much of the American PRT movement.

This essay is an attempt to critically examine the legacy of PRT activism in America: how that activism has sometimes been more of a liability than an asset, and how activists and entrepreneurs can realign their strategies to successfully develop an American PRT industry. First I will examine how PRT activism has traditionally failed to apprehend the complexities of the existing transportation industry; then I will examine the development of three historical parallels, to illuminate how other innovations – no less radical than PRT – have found success in the marketplace. Finally, I will show how these strategic lessons might be applied to the PRT industry.

## *A Misconceived Myth*

For decades, PRT activists have retold the same story: that the development of PRT has been ruthlessly suppressed by the established transportation industry – particularly Light Rail companies, which are completely impervious to innovation – in collusion with ignorant or corrupt politicians. According to this narrative, conquering such obstacles will require a David vs. Goliath-style conflict, with truth and innovation on our side, opposing stasis and corruption on theirs. LRT companies must be thwarted in their obstructionist ways, while politicians must be either educated or ousted, until they finally understand that PRT can do a better job than legacy technologies, at 1/10th the price. Once we have accomplished these things, PRT will finally be able to thrive.

The problem with this story is that it's simply not true. It's a myth with severely negative consequences. As the product of many battles against small-minded politicians and obstructionist LRT advocates, the origin of this myth is entirely understandable. Yet it is fundamentally wrong in both its diagnosis of the problem and its prescription for success.

For starters, the existing transit industry is *not* opposed to technological innovation. Like most businesses, transit companies have little ideology aside from profit. They do not care about innovation one way or the other, except where it impacts their bottom line, for good or for ill. In this case, the technological challenges posed by PRT are trivial; rather, it is the corresponding changes in profit models which make the mainstream transit industry doubtful of PRT. That is a critical distinction, because unless we correctly apprehend the locus of their opposition, we cannot form strategies to circumvent it.

Consider the mass transit industry's current business model, which nominally serves two different populations:

1.) Non-drivers (ie the young, elderly, poor, disabled, intoxicated, and so forth)
2.) Drivers, for whom fighting traffic congestion is even more aggravating than using mass transit.

The industry believes that both of these groups are extremely limited markets, albeit in slightly different ways. The non-drivers are a large group (some 20%-30% of the general population), but that market has already been captured. Moreover, non-drivers seem to be an inelastic market. The industry has observed that incremental changes in price or quality do not significantly affect transportation demand. When oligopolistic businesses operate in such a market, their optimal strategy is to provide the minimum degree of service necessary to capture the largest share of the market. Further improvements in service are not only unnecessary but undesirable, because additional investment will generate little new revenue.

The second market for mass transit is those who can drive, but under some circumstances would rather not. This market is also quite limited. In most circumstances, the operational advantages of the automobile – rapid, private, flexible, full-time, on-demand service – make it far more appealing than mass transit. The downside, of course, is traffic congestion. Larger issues such as accidents or global warming are too infrequent or impersonal to change people's behavior, but sufficiently awful traffic congestion will indeed convince drivers to switch to mass transit. So although this market is technically elastic, it is also directly in competition with the automobile. Mass transit systems can succeed in capturing the overflow that occurs once the roads have hit their saturation point. But by fractionally alleviating traffic congestion, mass transit makes the roads that much more appealing to use. Therefore investments and improvements in mass transit run up against rapidly diminishing returns, almost the same as when serving non-drivers.

Thus, public and private transport reach a roughly homeostatic balance, which is almost entirely determined by the saturation point of the road system, rather than the quality of the public transit. In most areas the balance is overwhelmingly skewed towards the automobile; the few exceptions are very high-density cities (London, Paris, Tokyo, Hong Kong, New York) where severe congestion occurs when even a small percentage of the population is driving. Yet even in those areas, any improvement in transit service is still in competition with the last. Once again, the optimal business strategy is to provide the minimum degree of service required to maximize ridership and revenue.[1]

[1] Some readers might decry this essay's economic orientation; surely the provision of a vital service like public transit is more important than mere profitability? There are two answers to this question. First, on the level of those who actually implement a system – whether investing their money in it or drawing their paychecks from it – economic concerns are paramount. Second, in this particular case, economic efficiency and the greater good are at least partially in alignment. When buses or trains operate near capacity, they make both economic and environmental sense. But during off-peak hours, the heavy vehicles must circulate around mostly empty. This not only requires a much larger operational subsidy, but also creates larger carbon footprints than if their few riders were in smaller single-occupancy vehicles. There may be social benefits to providing high-frequency, low-occupancy mass transit, but those are directly opposed to

The natural conservatism of the transit industry's profit model is exacerbated by the fact that virtually all mass transit is built under public contract. This either implicitly or explicitly places a cap on profit margins. Transit companies therefore have little desire to see lower-cost technologies emerge: if a company's profits are a fixed fraction of their costs, then high cost systems are explicitly in their interest! Given the choice between building a $500 million light rail system, or a $50 million PRT system that would serve exactly the same market, the transit industry will always choose the former. Not because they fear innovation, but because they fear losing 90% of their profits. Is it so strange that investors generally agree with them?

Another factor is at work: mass transit companies make their profits up front. They typically build and/or operate systems under a fixed contract, and when the contract is over, they can exit without risk. They lose nothing if the system does not perform as expected. Once the contract has been won, a contractor's profit is assured, provided that their cost estimates were correct.

In contrast, many PRT advocates – beyond emphasizing its fantastically low cost – often go on to propose that PRT is *so* cost-effective that it could be built and operated with entirely private funds, making a profit from farebox revenue alone. To the transit industry, this is an appalling suggestion: it seems that the PRT mafia intends to first slash their profitability by 90%, and then – by moving the profit-making mechanism to the uncertain tail-end of the process, rather than the assured beginning – open the door to eliminating profits altogether. For a risk-averse industry that makes guaranteed money on each and every contract, this looks like a plan for disaster. So, naturally, they oppose it.

Politicians also find PRT unappetizing, for similar reasons: many of their constituents would not benefit from lower costs. These constituents include the transit companies themselves, as well as associated local construction companies, sub-contractors, suppliers, transit worker's unions, and innumerable other institutions – all of whom currently profit from transportation spending, and would prefer it to remain as lavish as possible. This network of beneficiaries extends well beyond what is traditionally thought of as the mass transit industry: one recent light-rail project in Portland, for example, spent almost half of its budget on improvements to affected bridges, bringing highway contractors into the fold.

Because of this, many transit projects are now more concerned with creating jobs and disbursing public money than with actually providing transit. By this criterion, a politically "successful" project does not necessarily provide the most transportation benefit for the lowest cost, but instead distributes the maximum amount of money to the appropriate corporations, unions, and congressional districts. Lower-cost transit is clearly inimical to this – so why should they ever support it?

---

any economic or environmental benefits. PRT does not suffer from this defect, since it provides on-demand service during off-peak hours, without the need to wastefully circulate near-empty vehicles.

It should now be evident that when PRT advocates make their case by emphasizing its tremendous cost-effectiveness relative to conventional transportation, it threatens both corporations that fear the loss of their profits, unions that fear the loss of their jobs, and politicians who fear the loss of their pork. Their combined clout is infinitely greater than what PRT companies and advocates can ever muster; in direct confrontation, the establishment will win every single time. The truth will not prevail. For PRT advocates, confrontation has always been a losing strategy, and always will be.

What can be done? It may appear as though I am arguing, for cynical and Machiavellian reasons, that innovation cannot compete against entrenched convention. And that is indeed my basic argument. Yet PRT is hardly the first disruptive technology to arise, with the potential to wreak havoc upon the business models and political interests of massively powerful and entrenched incumbents. The obstacles now faced by PRT have occurred in many other industries – and have somehow been overcome. So let us consider the history of three other disruptive technologies: how they managed to gain a foothold in the face of indifference or opposition from the establishment, and how these examples can serve as lessons for the development of a viable Personal Rapid Transit industry.

## *Historical Analogues to PRT*

### Analogue #1: Personal Computers

This story is well known, so my comments will be brief. Personal Computers were, famously, not developed by the established computer industry. Aside from governments and large corporations, the establishment saw no market for computers. The idea of millions of ordinary people using computers in their daily lives was so silly that it was almost beyond contempt. It would be an unproven technology aimed at a non-existent market, which the fat and happy mainframe industry was happy to ignore. This left the field open for small, innovative, entrepreneurial risk-takers like Steve Jobs and Steve Wozniak.

It is fortunate Jobs and Wozniak lacked the resources to build mainframes: had Apple tried to compete directly against IBM or DEC – straight out of their garage – they would have been crushed like bugs. Instead, they were forced to develop products for market niches that the mainframe industry didn't believe existed. While this increased the apparent risk of their venture, it is also the only reason that they survived at all.

Even when the mainframe industry began to admit that consumers were indeed buying computers, it still believed that the much smaller profit margins on personal computers did not make for an attractive business. But personal computers had tapped into a classically elastic market, where modest decreases in price led to exponential increases in demand – a market dynamic utterly beyond the mainframe makers' experience or conception. So while the margins were indeed much lower than for mainframes, the sales volume soon became many, many, many orders of magnitude greater. The rest is history.

By the time that the personal computer industry began encroaching on mainframe territory, in the business market, it was too well established to kill.

In one respect, personal computers are not terribly analogous to PRT, in that they were developed soon after the essential underlying technologies had been invented, whereas PRT has been technologically feasible since the 1960s. Here, the history of containerization offers a better parallel.

## Analogue #2: Containerized Transport

Integrated containerized transport had been technologically feasible from the 1920s onwards, and was even intermittently demonstrated, without commercial success. These early experiments were viewed dismissively by the conventional "break-bulk" shipping industry, which saw little reason to invest in substantial innovation. As with the contemporary public transit market, oceanic shipping was believed to be a limited, inelastic market, which would not reward cost-cutting or improved capabilities.

By the 1950s, the volume of civilian oceanic shipping had been stagnant for decades. Almost all shipping was still conducted using archaic, time-consuming, labor-intensive techniques. The industry had developed a risk-averse culture that survived on government largess and price-fixing "conferences" – monopolistic cartels of shipping companies. This arrangement was good for everyone – governments, shipping companies, labor unions – except for those who might actually need to get something shipped (but that was hardly an important concern).

At the time, the industry relied upon surplus military freighters, which were almost free to purchase, but unsuitable for attempting full-fledged containerized transport. Due to the slow speed and small size of these ships, the industry understood "efficiency" purely in terms of space, rather than time. Ships spent weeks at port, painstakingly cramming every last crate, barrel and bag inside the curving contours of their holds. Early experiments with containerization had involved mixing bulky standardized containers with densely-packed breakbulk goods, resulting in the worst of both worlds: containers lowered the space-packing efficiency without generating any real improvement in labor costs or time efficiency. These experiments convinced the shipping industry that the promised benefits of containerization would always remain theoretical.[2]

Even if the industry had understood the value of time in the transport equation, it lacked experience with the kind of comprehensive, clean-slate R&D that containerization required. Containerization represented a true paradigm shift. It could not evolve from conventional breakbulk shipping in a piecemeal fashion: new types of containers, ships, trucks, railcars, high-speed cranes, and port configurations all had to be deployed simultaneously. This was completely beyond the conception or capability of the moribund shipping industry.

[2] Students of PRT history might spot similarities with Raytheon's PRT 2000, Morgantown, Aramis, or any number of other ventures wherein the hybridization of PRT with traditional mass-transit concepts produced disappointing "stuck in the middle" results.

Consequently, an outsider to the shipping industry, former trucking magnate Malcom Mclean, became the first to achieve true containerization. In 1954 he sold his trucking empire and founded Sea Land, which was relentlessly focused on the creation of universal containerized transport. Yet after developing and proving its technology, Sea Land did not immediately attempt to break into the trans-oceanic shipping market. Despite his considerable wealth and resources, Mclean understood that confronting the established industry would be suicidal – the hostile "conferences" were far too powerful. Instead, he made the seemingly quixotic choice to enter the coastal shipping market, a dying industry with little connection to trans-oceanic shipping.

At the time, coastal shipping was widely understood to be doomed. Its slow speeds and high labor costs left it unable to compete against the much faster and more innovative trucking companies (including, of course, Malcom Mclean's). In the 1950s, coastal shippers were carrying less than half as much cargo as they had during the Great Depression, and further decline seemed inevitable. As far the shipping cartels were concerned, Mclean was more than welcome to sink himself in unprofitable coastal shipping routes.

In 1956, Sea Land's *Ideal-X* sailed from Newark to Houston – the first true container ship voyage. When Mclean tabulated the cost of this very first run, he found that it had cost 75% less than a conventional break-bulk run would have been. With further refinements, Sea Land was able to decrease costs even further – by up to 94% in some cases. Once again, coastal shipping was competitive with overland shipping, and the applicability of containerization to transoceanic shipping was becoming obvious.

After establishing a secure foothold on the undefended coasts, Sea Land expanded into better-defended markets. It was slow going at first; the conferences (and their allied unions and politicians) fought relentlessly against containerization, with much success. Finally, after a decade of relatively slow growth, a breakthrough occurred: the escalating war in Vietnam created logistical demands that conventional shippers could not conceivably meet. To satisfy these requirements, fleets of large, fast containerships were soon carrying military supplies from ports on the US west coast to ports in Japan and Vietnam. At first, these ships returned to the US empty, because there was nothing worth carrying back from east Asia. Needless to say, that didn't last long. The rest, once again, is history: the availability of ultra-cheap shipping spurred the creation of new export industries, first in Japan, then Korea, then China and the rest of the East Asian Tigers. Before long, the volume of global trade had increased ten-fold, and virtually all of it was carried in containers.

As with the transition from mainframes to personal computers, the new industry was not so much cannibalizing an old market as creating a new one. And yet again, the key feature of this market was its elasticity. Another point of comparison is that profit margins in the new industry were lower than in the old, but this decrease was offset by a hugely increased volume of sales. Corporate profitability was not the only beneficiary of this effect: even as automation made shipping more efficient, its phenomenal market

growth actually created more jobs than were lost – jobs which were better-paying and less dangerous than the old longshore work had been.[3]

## Analogue #3: Private Spaceflight.

For those unfamiliar with this still-nascent industry, "private spaceflight" encompasses the recent flowering of private-sector space ventures, distinct from traditional government-backed space programs. Compared to personal computers and containerization, the history of this industry is almost unknown; therefore I shall spend a bit more time with it. Also, I am privileged to have played a (very minor and mostly inconsequential) role in its development, which has afforded me something of an insider's perspective. I believe that this industry offers particularly apt illustrations of the hurdles that disruptive technologies face in today's economic and political climate – especially in a context where market forces have become highly distorted by governmental subsidy and political patronage.

Before describing the development of the private spaceflight industry, however, it is necessary to dispel a few myths about the traditional space industry.

The first rockets to reach sub-orbital space were Nazi V-2s. After the war, both superpowers saw the military potential of rocketry, and absconded with as many German rocket scientists as they could get their hands on. In the frenzied space race that developed, expediency dictated that only the surest development paths be pursued, without regard for cost. In practice, this meant enlarging and elaborating upon the proven V-2 design, until rockets had become flying bombs the size of skyscrapers, which cost hundreds of millions of dollars apiece and were thrown away after every flight.

But expediency was neither cost-effective nor sustainable. The superpowers soon tired of the space race ("skyrocketing" and "astronomical" having become bywords for "mind-bogglingly expensive"), so they began looking for a way out. America reached the moon, declared victory, and left; the Soviets relaxed into a slow but steady rhythm of launching modest space stations, falsely claiming that they had never been interested in the moon in the first place. Rocket designs remained firmly grounded in their V-2 heritage, and launch costs remained exorbitant. On the American side – contrary to all supposed laws of progress –- spaceflight actually became more expensive, less reliable, and less capable. Human spaceflight continued, but strictly among the superpowers (joined by China, when it felt ready to claim that mantle), and strictly as a matter of keeping up appearances.

Despite the costs, several space applications became so essential that high launch costs were irrelevant: weather satellites, communications satellites, spy satellites, and later, global positioning satellites. These became so obviously important that a number of other countries developed indigenous launch capabilities, expediently copied from the basic Soviet and American designs.

---

[3] PRT proponents should keep this particular anecdote in mind when responding to job-loss concerns that politicians and transit unions will inevitably eventually raise.

For many aerospace engineers, the situation was profoundly frustrating. Famed airplane designer Burt Rutan likes to contrast the development of rockets with that of airplanes. In the four decades after the Wright Brothers flew at Kittyhawk, he points out, literally thousands of radically diverse aircraft designs were attempted – every conceivable combination of size, wing and tail configuration, propulsion system, fuselage shape, construction technique, control system, and so forth. All of the designs were sub-optimal, and many were downright catastrophic. Nevertheless, airplane design became perfected during this period through a process of Darwinian evolution. The fittest designs survived, passing their characteristics on to future generations of aircraft. After many iterations, the industry converged upon the highly optimized configurations that are still the basis of all modern aircraft.

In contrast, after the V-2, fewer than a dozen fundamentally different types of launch vehicle configurations were ever attempted. No real evolution could occur; the gene pool of rocket design, as it were, became increasingly inbred. After settling upon the first configuration that vaguely worked, the industry then proceeded to incrementally add grafts and implants as necessary.

Many aerospace engineers believed that there were a multitude of unexplored possibilities for launch vehicle designs, some of which might be vastly superior to the industry norms. Some became convinced that these alternative designs could be literally hundreds of times cheaper and safer than conventional rockets. Yet when these engineers showed their designs to the government or its prime contractors, they were met with disinterest and derision. By the early 1980s, many began turning to entrepreneurialism, convinced that the only way that innovation could occur was if they did it themselves.

But as entrepreneurs, they again failed to find success. Investors were difficult to find, and were easily spooked by sometimes overt interference from NASA and its prime contractors. Although a number of interesting and successful engineering prototypes were demonstrated, only one ever made it to market (Orbital Science's *Pegasus*) – and only after its costs had risen to the point that it was more expensive than its traditional competitors. The entrepreneurs (eventually calling themselves "alt.spacers," after Usenet groups where they engaged in perpetual and pointless technical debates) began to feel as though some invisible hand was blocking their success. Some became increasingly conspiracy-minded. The industry, meanwhile, mostly ignored the entrepreneurs' existence, or else treated them as pariahs. Spaceflight, the industry spokespeople often claimed, was intrinsically expensive: immutable laws of physics demanded that it be. Dreams of cheap and plentiful rockets would always be a folly.

By now, parallels to the PRT industry should be glaringly obvious. The entrepreneurs came to believe that both the government and the established industry were categorically opposed to innovation, had no real interest in space, and so forth. They often compared the established industry to a herd of lumbering dinosaurs, seeing themselves as the small-but-smart mammals scurrying underfoot. Evolution was undoubtedly on their side, they reassured themselves – or would be, rather, if those idiot dinosaurs would stop stepping

upon them. What the mammals failed to appreciate was that dinosaurs were neither stupid nor evil, but motivated by something far more difficult to overcome: basic self-interest.

The key to the dinosaurs' behavior was the perceived inelasticity of the space launch market. Each weather satellite, for example, arguably provides tens of billions of dollars of value during its lifetime. So even if it costs a few hundred million dollars to launch, a weather satellite is an unambiguously worthwhile investment. Yet the world only needs a dozen or so weather satellites – more would be pointlessly redundant. The resulting demand for weather satellites is both absolute and minuscule. Even if the price of launch were reduced from several hundred million dollars to zero, only a few weather satellites would be launched every year. Other established space applications show similarly flat demand curves, adding up to a total worldwide market for no more than a few dozen launches each year.

As in any market where competition is sparse, entry barriers are high, and demand is insensitive to price, suppliers had every incentive to keep their prices high. Many politicians also benefited from high prices, so long as high prices meant high costs, which translated into more federal money flowing into their districts.[4] With the government and its suppliers' interests thus aligned, the industry structured itself around the "cost plus" contract – an astonishingly brazen legitimation of wasteful spending. Under this scheme, contractors were reimbursed for any costs, "*plus*" an extra profit margin. This incentivized contractors to keep their costs as high as possible – and they became extremely accomplished at doing so.

The entrepreneurs were well aware of the meager demand from existing space applications, but theorized that cheaper launchers would enable various speculative space-based enterprises: space tourism, zero-gravity manufacturing, solar power satellites, asteroid mining, and so forth. But investors paid no heed to these untestable hypotheses. All they knew was that cheaper launch vehicles would disasterously cannibalize the existing launch industry. It would rob the industry of its profits and the politicians of their pork. Nobody in power wanted this to happen, and therefore it didn't.

Two things changed this.

The first was the advent of actual space tourism. Following the collapse of the Soviet Union, the Russians quickly become more capitalistic than their American counterparts, eventually offering to sell an otherwise empty seat on one of their flights to the International Space Station: $20 million for a week in space. Many were shocked when they found an eager buyer named Dennis Tito. NASA waged a desperate PR campaign to prevent Tito from flying, but in April 2001 the Russians launched Tito anyways, and his space holiday was a resounding success. The Russians had no difficulty selling the next empty seat, and then another, and then another. Soon, it became evident that even at $20

[4] I once saw a proposal for a government funding that listed, among the "technical specifications" of a vehicle: "subcontractors in 138 congressional districts." The company was awarded over a billion dollars, and never produced a single piece of flying hardware.

million per flight,[5] there was more demand for space tourism than the existing industry could possibly supply. This caught the attention of a number of adventurous investors, because unlike launching satellites, tourism is an undeniably elastic market. In other words, a market which would reward cost-cutting, rather than penalizing it. With this thought, a small but steady stream of capital began flowing to the entrepreneurs.

The second major factor was the X-Prize. In the mid-1990s, a space activist named Peter Diamandes began studying the early history of aeronautics, and observed that competitions and prizes had been a major impetus for its development. The $25,000 Orteig prize, for example, had prompted Charles Lindberg's trans-Atlantic flight, kick-starting the era of commercial aviation. Nothing similar had ever been attempted for space flight, so Diamandes proposed a $10 million purse for piloted, reusable, sub-orbital spaceships. The aerospace establishment scoffed at the notion – $10 million was what they spent to manufacture a single spacesuit, never mind an entire manned spacecraft development program – but dozens of entrepreneurial teams threw themselves into the race.[6]

When Burt Rutan won the X-Prize was won in October 2004, it was a shot heard round the world. A few critics noted that Rutan's *SpaceShipOne* had merely replicated the flights of the X-15 – an experimental military spaceplane from the 1960s, the further development of which had been shelved during the race to replicate the V-2 – but proponents pointed out that Rutan had done so at an inflation-adjusted 1/100th the cost. The long-held myth that spaceflight could never be done more cheaply, and could only be done by governments, was dead forever.

Suddenly, investors became almost easy to find. Rutan soon struck a deal with Richard Branson, whose "Virgin Galactic" space tourism company should be flying fleets of suborbital spacecraft before the decade is out. Meanwhile, Amazon.com founder Jeff Bezos is running a company called "Blue Origin," which is now conducting secretive flights from his private spaceport in west Texas. Hotel magnate Robert Bigelow has committed over a half billion dollars to the development of radically cheaper space stations, and already has two small unmanned stations in orbit. Paypal.com founder Elon Musk has put most of his fortune into SpaceX, which is developing a line of reusable orbital rockets. Celebrity video game designer John Carmack has taken a uniquely hands-on approach; his homespun "Armadillo Aerospace" began as a weekend hobby welding

[5] Along with the rather onerous requirement that the buyer pass several months of cosmonaut training and learn to speak Russian.

[6] Rather cheekily, Diamandes didn't *have* $10 million at the time, or actually any money at all. Instead, he spent several years raising $5 million from thousands of believers, and then made a brilliant double-or-nothing bet with an insurance company (called a "hole-in-one" policy). Diamandes knew that the insurance company would do its due diligence by contacting NASA, Boeing, and Lockheed Martin, and other allegedly credible sources, which he trusted would spout their usual rhetoric about the fundamental impossibility of cheap spaceflight. Thus Diamandes succeeded in converting the establishment's hostility towards entrepreneurial spaceflight into a $10 million purse for the entrepreneurs. This prompted perhaps $50 million of R&D among the various X-Prize competitors; Richard Branson then made a $125 million investment in the winner, and the State of New Mexico followed up with a $250 million investment in Branson's spaceport. If the industry had been any less skeptical, none of this would have happened.

together improbable-looking rockets with some friends, but has evolved into a highly respected company that is winning contracts and breaking rocketry records on a monthly basis, with vehicles that are literally hundreds of times cheaper than their predecessors.

These are just a few highlights; dozens of other companies are pursuing specific niches within this new industry – moving beyond engineering to include specializations such as insurance and market research. The private space race has also spread beyond America, with well-funded companies developing vehicles in Canada, Europe, and South Korea.

Even governments have gotten in on the act. In the wake of the X-Prize's success, congress ordered NASA to develop a series of "Centennial Challenge" prizes. The state of New Mexico committed $250 million for a public spaceport – With Virgin Galactic as the anchor tenant – while Oklahoma put $40 million into tax credits for entrepreneurial space companies, and has been promoting the use of a decommissioned air base as a commercial spaceport. Sill other commercial spaceports are being planned, from Nova Scotia to the United Arab Emirates.

In half a decade, Private Spaceflight went from being a discredited pipe dream with almost no funding, to a respectable industry with several billion dollars of capital. It must be acknowledged that the industry is not yet cash flow positive. Although a few companies are now generating modest profits (mostly by supplying low-cost components and services to other entrepreneurs), a truly viable and self-sustaining industry is still a few years away, but at least the entrepreneurs are finally getting their chance to *try*. All in all, it has been a remarkable reversal of fortune.

But what about the aerospace establishment, which had previously obstructed such entrepreneurial efforts – did it simply roll over and die? Not at all: its attitude has ranged from benign neglect to beneficent engagement. The reason for this attitude change is simple: its profit centers have not been particularly threatened. With the exception of Elon Musk's SpaceX (a self-funded venture that is difficult to obstruct), the entrepreneurial ventures have largely avoided targeting the orbital launch market. By focusing mostly on sub-orbital human spaceflight – a market that didn't even exist, in the eyes of the established industry – the alt.spacers ceased to be an imminent threat. Now, they have too much momentum to stop.

## *The Aftermath of Innovation*

Within each of the three industries I've profiled, the innovators have dismissed the establishment's conservatism as mere small-mindedness: myopic, hidebound, and gutless. There's some truth to this, but it's a more complex story than that.

For large and secure companies in mature industries, there is little sense in embarking upon risky ventures that may do nothing more than cannibalize their own profit centers. Nobody wants to vivisect a healthy cash cow, and even if a company's management wished to do so, shareholders in these kind of companies are typically quite risk-averse, and would surely reject such adventures.

Secure companies in mature industries therefore often miss the next wave of innovation, stubbornly sailing their outmoded technologies into the grave. Some large companies, however, develop more cunning strategy: while jealously guarding their existing profit centers, they essentially outsource the risk of discovering new profit centers to unwitting third parties. If an interesting new technology arises, the established player will dismiss it at every opportunity.[7] However once the new technology crosses a certain threshold of profitability, even the most tradition-bound company can abruptly change its tune.

In many respects, the dinosaur vs. mammal analogy was more apt than the alt.spacers intended. First: there were profoundly good reasons why mammals evolved beneath the bushes, rather than challenge Tyrannosaurs or Brontosaurs in their own ecological niches. And second: some dinosaurs never went extinct at all, but evolved into birds.

In the computer industry, success for Apple and others didn't mean extinction for old dinosaurs like IBM and HP. On the contrary, once the viability of the personal computer market had been proven beyond a doubt, those dinosaurs rapidly grew wings, and their sales soon outpaced Apple's. The same process had occurred with containerization: even while traditional shipping companies ridiculed and dismissed Sea Land, many of them, seeing what the *Ideal-X* had done, began developing their own containerization systems. Soon, a myriad of incompatible containerization systems had emerged. In the end, the widespread adoption of containerization did not occur until after the various competitors managed to sit down hammer out a common standard – and Sea Land, by then, was hardly the only company at the table.

Finally, in the private spaceflight industry, a similar process is now under way. Established firms are moving into this market, either through imitation or acquisition. European aerospace giant EADS/Astrium has proposed their own space tourism vehicle, which plainly borrows its design from several entrepreneurial efforts. Northrop-Grumman purchased a 100% stake in Burt Rutan's Scaled Composites, thereby securing a major stake in the new industry. Meanwhile, Lockheed Martin has been aggressively bidding against SpaceX to provide launch services for Robert Bigelow's stations. Now that they are trying to break into a new and elastic market that may be much larger than their old inelastic market, the prices that Lockheed Martin is offering are rumored to be several times cheaper than what they have traditionally charged for satellite launch.

## *Lessons for PRT*

PRT developers and advocates can derive numerous of lessons from these historical anecdotes, in regards to the business and political responses to disruptive technologies like PRT. Fundamental to all of these lessons is the necessity of dropping the myth of heroic confrontation. PRT advocates are not engaged in a struggle between good and evil, or even between the old and the new. The mass transit industry is not Goliath, and we are not David. If advocates continue to frame themselves within this narrative, they will keep

[7] cf. Microsoft's attitude towards the Internet prior to about 1996, IBM's attitude about personal computers in the 1970s, et cetera. The list is endless.

firing their slingshots in wholly unproductive directions, when they mostly shouldn't be using their slingshots at all.

## Lesson #1: Disruptive technologies should seek uncontested niches

Building a better mousetrap is one of the worst ways to get the world to beat a path to your door. The degree to which new products succeed has more to do with the field that they compete upon than with the products themselves. If the field is well-defended by established players – the old makers of mousetraps, as it were – then they will have an almost insurmountable home-field advantage. Far better to fight on the field of one's choosing – or, better yet, to not fight at all.

For as long as the space entrepreneurs focused on breaking into the satellite-launching business, they were doomed to dash themselves against the tremendous political and economic clout of companies like Boeing and Lockheed Martin. They only found some breathing room after they began focusing on markets that the established players didn't care about. The same pattern can be seen in the development of personal computers and containerization, and will doubtless be repeated during the development of PRT

Thus PRT should first establish itself on the periphery of the conventional transit market. If it is successful in these niches, it will expand into further markets, eventually swallowing the very industry that it must presently tiptoe around. Conversely, if PRT cannot succeed in creating substantial new markets, then investors will rightly perceive it as nothing more than a complicated way for the mainstream transit industry to make a lot less profit, and PRT will never receive the resources to develop.

What could these initial niches be? Corporate campuses are an obvious example, as no conventional transportation technologies currently occupy that niche. Moreover, the return on investment can be uncommonly easy to calculate.[8] Such relatively straightforward cost/benefit calculations would be more convincing to investors than the inevitably murky calculus of publicly-financed transportation projects, and the market positioning should not provoke a response from any currently-established players, since in that market, there aren't any.

Other appropriate niches may be those in which no player or technology has become dominant – malls, airports, hospitals, theme parks, factories, et cetera. Still other niches may include new types of urban developments where the design requirements explicitly preclude conventional transit – Al Masdar being a prime example of this.

These suggestions may seem rather obvious in hindsight, given the developments at Heathrow and in the UAE. But it's important to note what are *not* appropriate niches at this time: projects that would traditionally be awarded to conventional transportation

[8] If a $100m PRT system can save 5 minutes per day for each of 40,000 employees, then it would save 833,333 employee-hours per year. If those employees are worth $40 per hour, the system would save $33.3m per year, yielding a 3-year ROI on the capital costs (obviously not considering any farebox revenue, O&M costs, the value of the social and environmental capital it would produce, and so forth).

systems, such as urban light rail networks. Unfortunately, in their zeal to topple Goliath, this is where PRT advocates often direct their efforts, to no good effect whatsoever.

## Lesson #2: Disruptive technologies evolve cooperatively with their predecessors

As personal computers began to expand out of their initial niches and into the more traditional business market, they did not instantaneously usurp the role of mainframes. In fact they often cooperated with the older technology, by working as overly smart terminals that continued to provide access to the functionality of the mainframe. Eventually it became obvious that these precocious new terminals offered capabilities and conveniences that rendered the mainframes obsolete, but this incremental and symbiotic process gave the more agile mainframe companies enough maneuvering room to join the personal computer industry themselves.

Similarly, much of the private spaceflight industry has thus far been beneficial to the aerospace establishment. Several entrepreneurial companies have developed low-cost micro-satellite technologies, which pose no immediate threat to the makers of conventional satellite systems, but which have created entirely new customers looking for orbital launches – something that only the established industry is currently able to provide. In this and numerous other ways, the establishment is finding that it can profitably do business with the entrepreneurs, while gradually positioning itself to adopt any successful profit models that may emerge from the private spaceflight industry.

Analogously, the PRT industry needs to find synergies with conventional transportation systems. For example, small PRT networks can function as collectors/feeders at rail stations, greatly expanding the effective service areas. This would increase rail ridership, while also permitting the rail stations to be spaced further apart, boosting the rail system's overall speed. Far from being an imminent threat to existence of rail, PRT can actually enhance the effectiveness rail networks, thus establishing a secure position for itself within the existing transport industry.

But hold on a minute: won't the superior service offered by PRT eventually become a threat to rail? Yes, almost certainly. PRT networks have the unique capability of organic, ad-hoc expansion, and as the PRT feeder systems expand, they will eventually become interlinked. People will then find that it makes more sense to travel directly from one PRT station to another, rather than transfer multiple times between inconveniently scheduled rail services. Consumer tolerance of modal shifts will diminish, while demand will grow for higher-speed PRT backbone lines, so that even long-distance travel can be accomplished via continuous PRT. Eventually, trains will be as common in cities as mainframes are in offices.

This distant eventuality, however, shouldn’t trouble the rail companies. For one: if PRT improves their bottom line today, then what it will do in a decade or two is frankly less of a concern. More fundamentally, the incremental nature of this transition will permit the

more agile rail companies to transition themselves into the PRT industry, either through acquisition or imitation – just as with any other disruptive technology.

## Lesson #3: The markets that disruptive technologies create are more significant than the markets they usurp.

Developing PRT systems in uncontested niches is not merely a strategic feint; it is an essential part of demonstrating the viability of any disruptive technology. No disruptive technology can succeed unless it taps into a broader, deeper, or more profitable customer base than its predecessors. Developing a new niche is a tangible way to prove this.

Niches are one good way to gain a foothold; the next step is to demonstrate new market dynamics. As explained at the beginning of this essay, the existing mass transit industry is based around the exploitation of markets that it assumes are both small and inelastic. They've gotten very good at extracting value from these markets, and if those markets are truly as limited as they appear, then it is unlikely that any new technology could extract more value from them. If PRT intrinsically less profitable than the established industry, then investors will never be favorably disposed to it.

Containerization, for example, did not succeed because it could merely move the same volume of goods as break-bulk shipping, across the same trans-Atlantic routes. Nor did it succeed because it could do these things at a lower cost (which, from the investor's end of the telescope, would just amount to less profit). If that's all that containerization had done, then it would have failed miserably. The reason it succeeded is because it enabled a hugely increased flow of goods, across a variety of entirely new markets, particularly in East Asia. This is the nature of disruptive technologies: they don't succeed when they merely outperform their predecessors in conventional ways; they succeed when they do what their predecessors fundamentally cannot.

For PRT to succeed, it must demonstrate the ability to create markets or market dynamics that could not otherwise exist. Uncontested market niches are the first step; demonstrating greater demand elasticity is the second. If PRT prompts non-drivers to take significantly more trips than they otherwise might, or entices drivers to ride the PRT even when the roads are uncongested, then that will demonstrate the existence of a profoundly different market dynamic. Such markets would dwarf the current market for mass transit, leaving one to wonder why it was ever worth contesting in the first place.

To actually demonstrate this elasticity will require competing in the existing market, which PRT companies are not yet in a position to do. But the imperative to eventually do so should shape the arguments that PRT advocates use today. Our argument should never be that PRT can merely do what mass transit does, only more cheaply: that can always be turned around to make PRT look like a marginal proposition to investors. Rather, our argument should always be PRT can do vastly *more* than mass transit ever could – thus shifting the focus from the lower margins to the higher volumes.

## Lesson #4: There are no successful technologies – only successful business models

The technological aspects of PRT are not, in themselves, particularly important. This can be a bitter pill to swallow, as most PRT enthusiasts[9] are technophiles who become easily enamored of elegant engineering. But the rest of the world doesn't work that way.

Apple's personal computers did not succeed because they were technologically "better" than mainframes. Relative to the best practice of the day, Apple's machines were frankly crude. This didn't matter in the slightest, however, because they made a lot of money in markets where mainframes never could. That is the sole reason why Apple prospered – their technology, by itself, had little to do with it. When IBM began producing its own personal computers, their machines were inferior to Apple's in many respects, but their business models were better, and they rapidly gained market dominance.[10]

This was an issue that confoundedthe private spaceflight industry for decades. During the 1970s and 1980s, the entrepreneurs – who were engineers first, and businessmen second – focused almost exclusively on how stupendously great their technology would be. That didn't get them many investors. In the 1990s, they began focusing on how much value their technology would create for space-launch customers; that didn't get them enough investors, either. Finally, in the 2000s, they began to talk about how much value their ventures would create for investors, and what do you know? The investors showed up.

So when advocates extol the virtues of their technology relative to their competitors – better comfort & speed, no waiting, et cetera and so forth – they are mostly wasting their breath. PRT will indeed offer many such tangible benefits to consumers, but consumers aren't the ones who will invest in R&D (which is what most PRT companies now require), and consumers aren't the ones who will purchase and install PRT systems (which is the stage that ULTra and Vectus have reached). Instead, the focus needs to be on how PRT will generate positive returns to its investors – and investors know that creating benefits for consumers does not automatically translate into financial returns.

At the same time as PRT advocates love to praise their own technology, they equally love to denigrate other transport technologies. They enjoy pointing out how older transport technologies are worse in almost every conceivable way, and there is a smug and unbecoming sense of schadenfreude among many PRT advocates whenever any mass transit project fails or under-performs in some capacity.

---

[9] Myself above all!

[10] For me, the most heartbreaking illustration of this is the Commodore Amiga: a personal computer released shortly after the Apple Macintosh, which was immeasurably better than its competition. It was 10-15 years ahead of its time, boasting features like photo-realistic graphics, symphonic sound, and preemptive multitasking. It was also half the price of the Macintosh, and inspired devotion among its user base that surpassed religious fanaticism. Having created an infinitely superior mousetrap, Commodore rested on its laurels and waited the world to beat a path to its door. Predictably, the company was dead and gone within a decade: its business model – where one could discern that such a thing even existed – had been terrible; its unbeatable technological superiority had been completely squandered.

This a grave mistake. Not because PRT isn't superior to its predecessors (it is), and not because it offends the purveyors of those older technologies (they can take it). Rather, this attitude has alienated what ought to be the single greatest single source of public support for PRT: transit riders themselves.

## Lesson #5: Don't alienate your allies

Until now I have emphasized somewhat indirect strategies and tactics as the best means of getting PRT established in the market: avoid direct confrontation with other technologies, while seeking ways to cooperate with (and eventually co-opt) their existing markets. In the short term, I believe that this is certainly the best approach – however in the longer term, as PRT systems become increasingly large and inevitably more political, the industry will need to develop something it currently lacks: a constituency.

Imagine the political impact of tens of millions of people clambering for PRT to be installed in their cities. At present this is a fantastical proposition, which even the most wild-eyed PRT advocates could hardly dare to envision – but I believe that such a scenario may eventually be possible. Traditional PRT advocacy, however, is currently undercutting the development of this movement.

When PRT advocates dare to imagine such scenarios, they generally conjure one of two scenarios: either a mass outbreak of environmental consciousness, with citizens demanding more sustainable forms of transport, or else a mass uprising of frustrated commuters, demanding alternatives to being perpetually stuck in traffic. Neither scenario is remotely realistic. Consciousness-raising, by itself, is too ethereal to translate into built hardware, while traffic congestion has never inspired anything fiercer than apathy. The first real constituency for PRT, if such a thing is even possible, will come from another quarter entirely.

At the beginning of this essay, I discussed the two constituencies that mass transit now serves: those who use it as an alternative to driving, and those who cannot drive at all. “Transit” means very different things to each group. To the former, it is a convenience to use if the roads are clogged. To the latter, it is the ability to be a functioning member of society.

American concepts of citizenship are inextricably tied to mobility. One's first car is the material initiation into adulthood, and the Driver's License is the *de facto* form of official identity. For non-drivers, being excluded from this is not a mere cultural handicap. Those who rely upon mass transit live under constraints that most drivers can barely imagine. In many areas, the majority of jobs are either temporally or spatially inaccessible by transit. For the few jobs that they can reach, missing an hourly bus by 10 seconds can mean being fired. Other everyday tasks like shopping, visiting friends, or going to a doctor, are similarly constrained. If transit riders want to be certain not to miss their buses or trains, they must constantly spend long periods waiting in unsafe or unpleasant environments. Even for the relatively few locations that they're able to reach,

non-drivers always live under the threat of curfew, forced to scramble home before the last bus of the evening. For most of the car-driving population, such restrictions would seem like the stuff of remote and totalitarian societies, but non-drivers deal with such constraints every single day.

Yet for all of its egregious faults, mass transit is the only route to functional citizenship that non-drivers have. It's a fourth-class form of citizenship to be sure, but it's still better than nothing at all. Consequently, non-drivers are extremely defensive of it. Threats to mass transit are, in a very real and present sense, threats to their existence within society.

One might think that non-drivers would already be clambering for PRT. For those of us who understand how it works, we know that PRT would make their lives immeasurably better – on par with drivers, in many respects: first-class citizenship at last! So why haven't non-drivers embraced PRT?

I've talked with many public transit advocates about this, and it's for one simple reason: they feel that mass transit is currently the only game in town. And in a very real sense, they're right. PRT is not ready for large-scale deployment. Even if the existing technology is completely flawless and infinitely scalable, it is currently impossible, from a simple project-management point of view, to deploy PRT systems over large urban areas. Such projects are much more complex than just scaling up the process of building a small test track – which is as much experience as any company presently has. The intricacies of building and operating large-scale urban PRT networks will have to be learned experientially and incrementally, as is well understood by anyone familiar with the political and managerial intricacies of transportation projects. When a PRT company naïvely claims that, given sufficient money, it could build a full urban network – without having built so much as a full test track – this discredits PRT in the eyes of everybody who knows better. At present, all credible PRT projects are necessarily small-scale; in a few years, the lessons of these small-scale project can be applied to medium-scale projects. Large-scale projects will be feasible a few years after that, but they're not realistic right now.[11]

So when PRT advocates take pot shots at conventional transit projects, they are criticizing something to which they can *currently* offer no viable alternative. For drivers – who generally think of mass transit as a minor convenience at best – such slights cause little harm. But to those for whom mass transit is a vital lifeline to civilization, it is an indefensibly hypocritical assault upon their very existence. For these transit advocates, anything that threatens to restrict or delay the expansion of their transportation options is effectively an attack upon their civil rights. It isn't possible to argue that PRT will give them vastly better transit opportunities than they have today, if only they would wait a few years. Access to civil society is not something that can be gamed; the promise of

[11] Partnering with companies that have experience managing large-scale projects may accelerate the learning curve. Both ATS and Vectus are doing exactly this, via their associations with BAA, ARUP, and Posco. Such allies will lend vital experience that can accelerate the development of medium- and large-scale PRT systems, but it will not change the basic order of development. In fact, companies such as these will be *especially* cognizant of the fact that one must crawl before one can walk or run.

first-class citizenship at some indeterminate point in the future will *never* be worth the sacrifice of their present options, however meager those options might be.

And yet, the fact remains that PRT will be a tremendous boon to this constituency, once it becomes available to them. In the meantime, PRT advocates should take pains not to alienate this group. There is no good that can come from doing so, and much ill.

Currently the non-driving demographic is of little political significance – actually, it is probably the single most marginalized constituency in America, if only because it is so difficult to mobilize.[12] However, I suspect that the prospect of first-class citizenship, once it is within both their imagination and their reach, may be compelling enough to get them fired up. If the urgency and righteousness of their cause is finally aligned with both environmental sustainability and economic rationality, then this could become an extremely powerful social movement indeed. The development of this movement would be greatly hastened, however, if we haven't unintentionally burnt every bridge to that community long before this opportunity arrives.[13]

## Lesson #6: Competition is not only about winning and losing

Given the patterns of failure and success for other disruptive technologies, it should be clear that the establishment of PRT will depend on more than its technical or economic characteristics. Even with a flawless design and an otherwise superb business plan behind it, any given PRT effort could still be scuttled by social or political factors. Because these factors are currently interwoven with the established transportation industry, it is imperative that PRT advocates seek to understand them.

Although better understanding could conceivably aid in the development of superior offensive strategies, that is not the point. Given the tremendous disparities between the incumbents and the innovators, it is unlikely that any confrontational strategy – no matter how well conceived – can be successful.

PRT advocates should ask themselves: what are the boundaries of the current transportation industry? Which territories will it fight over, and which will it leave uncontested? Who are the friends and beneficiaries of the established order, and how do they benefit? How can we bring them additional benefits, without also threatening their present standing? How can we compliment and extend the established order – or even make it dependent upon us?

The strategies that emerge from these questions will not result in a "loss" for the establishment. If we are successful, the established order will more or less continue – but it will continue with PRT. It will acquire the technical characteristics of PRT, even as the PRT industry becomes integrated into the socio-political web of the incumbent

[12] And I don't mean figuratively.

[13] Admittedly, it is one single pro-transit activist, rather than anybody in the PRT camp, who done the overwhelming majority of egregious and intentional bridge-burning. Nonetheless, the disposition of many PRT advocates has quite unintentionally poured fuel on those fires, which is a shame.

industry. In the end, the two industries will be one and the same. It will have been a win for everyone.

This is not to say that the merger will be straightforward, harmonious, or even particularly willing. There will be much stubbornness and institutional resistance on both sides, and successful strategies will require a delicate balance between avoidance, co-operation, co-optation, and assimilation. But head-on confrontation alone will never produce success.

In conclusion, it is my hope that PRT advocates can lay down their rhetorical slingshots. Our confrontational strategies and attitudes vis-à-vis the established industry have made us like bees stinging a rhinoceros: mildly irritating to the rhino, but invariably lethal to us. It is time for another approach – one that learns from the mistakes of the past, and seeks to build alliances at every opportunity.

*"To fight and conquer in all your battles*
*is not supreme excellence;*
*supreme excellence consists in*
*breaking the enemy's resistance without fighting."*

*– Sun Tzu, The Art of War*