Tragedy of the Regulatory Commons:
LightSquared and the Missing Spectrum Rights

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The endemic underuse of radio spectrum constitutes a *tragedy of the regulatory commons*. Like other common interest tragedies, the outcome results from a legal or market structure that prevents economic actors from executing socially efficient bargains. In wireless markets, innovative applications often provoke claims by incumbent radio users that the new traffic will interfere with existing services. Sometimes these concerns are mitigated via market transactions, a la "Coasian bargaining." Other times, however, solutions cannot be found even when social gains dominate the cost of spillovers. In the recent "LightSquared debacle," such spectrum allocation failure played out, killing the entry of a nationwide, state-of-the-art, 4G network; GPS interests, using a neighboring band, lobbied for the outcome. Yet, the most conservative estimates place the 4G gains at least an order of magnitude above GPS losses. Transaction costs -- caused by policy choices to issue limited and highly fragmented spectrum usage rights (here in the GPS band) -- proved prohibitive. This provides a template for understanding market and non-market failure in radio spectrum allocation.

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I. INTRODUCTION AND BACKGROUND

> Scarcity of private spectrum, the limitations of commons networks, and the waste of public spectrum go a long way toward explaining bottlenecks in U.S. wireless broadband.[3]

In early 2012, regulators at the Federal Communications Commission (FCC) took an abrupt about-face with respect to a key, if obscure, public policy. In 2003 and 2004, the agency had authorized the use of satellite frequencies, allocated to the co-called L Band, to also be used in terrestrial wireless systems -- "cellular."[4] The ruling allowed (in fact, mandated) continued performance under the license's original terms for satellite phone service, while permitting the carrier to additionally supply land-based cellular service -- rights called the "ancillary terrestrial component," or ATC.

Through a complicated set of actions involving satellite licensees, bankruptcy courts, investors, and additional FCC rulings, the opportunity permitted in 2004 was finally coming to fruition by year-end 2011. LightSquared, which had purchased the satellite licenses, broke ground on a 4G (fourth generation) high-speed wireless broadband network using LTE (long-term evolution) technology, expending some $4 billion in capital.[5] The system would begin service in mid-2012 and, on completion by 2015, would cost a projected total of $14 billion.[6] The network would serve tens of millions of wireless subscribers in competition with mobile carriers such as Verizon Wireless and AT&T Mobility.

The Commission lauded this competitive addition to the broadband marketplace. It included the 40 MHz of L Band frequencies as a featured component of the National Broadband Plan, issued March 2010, which committed the agency to adding 300 MHz of spectrum for mobile wireless services, in total, by 2015.[7]

But on February 14, 2012 the U.S. Department of Commerce posted a nasty valentine. Acting on complaints from the Department of Defense, the Federal Aviation Administration, and other parties following 2011 radio receiver tests, the Department of Commerce sent the FCC a letter stating that the emerging 4G network would interfere with GPS (global positioning satellite) receivers, which use frequencies adjacent to the L

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[3] MICHAEL HELLER, THE GRIDLOCK ECONOMY 91 (2008).

[4] For the history of the proceeding, *see* FCC, In the Matter of LightSquared Technical Working Group Report: Comments in Opposition of LightSquared, Inc., IB Docket No. 11-109, DA 12-214 (Mar. 16, 2012) ("LightSquared FCC Comment").

[5] Tiffany Kay & Michael Bathon, *LightSquared Files Bankruptcy After Network Blocked*, BLOOMBERG (May 15, 2012).

[6] Scott Moritz & Olga Kharif, *LightSquared Blow Gives Falcone Few Options to Salvage Value*, BUSINESSWEEK (Feb. 21, 2012).

[7] FCC, NATIONAL BROADBAND PLAN 87 (2010).

Band.[8] Ironically, the complaint was *not that LTE emissions would spill* into the GPS band, but that GPS receivers, long made to "listen in" to lightly-used neighboring frequencies, would suffer diminished performance due to the *increasing L Band traffic*.[9]

Immediately, the FCC stated that it was suspending LightSquared's ATC authorization and would revoke the agency's 2004 ruling creating it.[10] Three months later LightSquared declared bankruptcy.[11] In 2013, at the time of this writing, the firm remains mired in financial restructuring efforts and all work to construct a new LTE network is halted. The smoldering wreckage of the scuttled nationwide network provides a thematic logo for the process of spectrum rights definition at the FCC.

Even senior FCC officials were stunned by the sudden regulatory reversal.[12] The LightSquared LTE network promised to deliver orders of magnitude more economic value than would be lost by resulting interference to GPS. A well-ordered rights assignment in the GPS band could not only fully protect GPS users, including mission-critical tasks using GPS devices, but improve wireless services available to those parties. In other words, whatever gains were achieved by the GPS interests lobbying against LightSquared's ATC venture came at a price that turned the great majority of GPS users into net losers.

This "non-market failure" resulted from the manner in which legal rights to spectrum use were defined and assigned. In Garret Hardin's terminology, it is a "tragedy

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[8] Letter to Julius Genachowski, Chairman, Federal Communications Commission from Lawrence E. Strickling 2, Assistant Secretary for Communications and Information, U.S. Dep't of Commerce (Feb. 14, 2012) ("NTIA Letter"). The letter's language is quoted from Letter from Ashton B. Carter, EXCOM Co-Chair, Deputy Secretary of Defense and John D. Porcari, EXCOM Co-Chair, Deputy Secretary of Transportation, to Lawrence E. Strickling, Assistant Secretary for Communications and Information (Jan. 13, 2012). EXCOM is the Executive Steering Group of the Interagency National Executive Committee for Spaced-Based Positioning, Navigation, and Timing. *See also* Petition for Reconsideration of the U.S. GPS Industry Council, ET Docket No. 10-142, June 30, 2011 (for reconsideration on the *2011 MSS ATC R&O* on the Radionavigation-Satellite Service ("RNSS") and commercial GPS).

[9] This type of interference is called "overload."

[10] FCC, Statement from FCC Spokesperson Tammy Sun on letter from NTIA addressing harmful interference testing conclusions pertaining to LightSquared and Global Positioning Systems, Press Release, Feb. 14, 2012; FCC, *International Bureau Invites Comment on NTIA Letter Regarding LightSquared Conditional Waiver: Public Notice*, IB Docket No. 11-109 at 4 (Feb. 15, 2012).

[11] Tiffany Kary & Michael Bathon, *LightSquared Files Bankruptcy After Network Blocked*, BLOOMBERG (May 15, 2012).

[12] Blair Levin, chair of the National Broadband Task Force (2009-2010) at the FCC, summarized the regulatory outcome this way:

> Something extraordinary happened last week. Our country reallocated 40 MHz of commercial spectrum. No Notice of Proposed Rulemaking from the FCC. No notice and comment period. No economic analysis. Not even a legal decision stating that that is what we are doing.

Blair Levin, *Remarks to the Minority Media & Telecom Council*, MINORITY MEDIA & TELECOM COUNCIL, (Mar. 8, 2012).

of the commons."[13] Michael Heller refined the concept, in this context, to a "tragedy of the anti-commons."[14] Lee Anne Fennell, providing a synthesis, shows the problem to be a generic "common interest tragedy."[15] In this paper, we elect to add further to terminology creep by dubbing the situation a *tragedy of the regulatory commons*.

The primary alternative account frames the "LightSquared debacle"[16] as an arcane dispute over highly technical measures of radio interference.[17] It is that complexity – the nature of the beast in busy wireless markets deploying advanced technologies -- that is said to cause the frustrating, anti-social outcome. In particular, some spectrum experts suggest that, because the engineering requirements for radio equipment – specifically, GPS receivers – are not sufficiently defined by regulators, the border between the L Band and the GPS Band was murky.[18] They point to this lack of technical specificity as the heart of the problem, the solution lying in greater diligence by regulators to define precisely what constitutes "harmful interference." Proposals are being made, for instance, to begin more careful government regulation of GPS receivers, prohibiting the production and sale of cheaper models that are susceptible to quality diminution from traffic in neighboring frequencies.[19] The idea is that, by forcing the market to produce better-performing, if more expensive, radios, regulators will face less pressure to protect existing users from transmissions generated by entrants within – or across – allocated bands.[20]

However, the real lesson learned from the LightSquared debacle is contained in the simple logic of "tragedy of the anti-commons," laid out elegantly in law professor Michael Heller's work,[21] in the economics of Nobel Laureate James Buchanan and Yong Yoon,[22] and elsewhere.[23] Moving wireless markets forward to grasp the enormously

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[13] Garrett Hardin, *The Tragedy of the Commons*, 162 SCIENCE 1243 (1968).
[14] Michael A. Heller, *The Tragedy of the Anticommons: Property in the Transition from Marx to Markets*, 111 HARV. L. REV. 621 (1998); Michael Heller, THE GRIDLOCK ECONOMY (2008).
[15] Lee Anne Fennell, *Common Interest Tragedies*, 98 NW. L. REV. 907 (2004).
[16] Cecilia Kang, *FCC treading lightly after LightSquared debacle*, WASH. POST (Feb. 15, 2012).
[17] *See* J. Pierre De Vries, *Optimizing Receiver Performance Using Harm Claim Thresholds* (University of Colorado at Boulder Law School paper, 2013); Jon Brodkin, *Why LightSquared failed, It was science, not politics*, ARS TECHNICA (Oct. 1, 2012) ("In the end, though, it was not politics, but the results of repeated tests which the FCC could not ignore, that thus doomed LightSquared."); David Schneider, *LightSquared's GPS-Interference Controversy Comes to a Boil*, IEEE SPECTRUM (Feb. 2012) ("But more levelheaded engineers have also scrutinized the problem in detail, and the technical issues appear to be understood well enough to suggest possible work-arounds.").
[18] *See* Stephen Lawson, *LightSquared vs. GPS Raises Big Spectrum Issues*, PC WORLD (July 25, 2011) (citing experts discussing the receiver issues).
[19] *See* J. Pierre De Vries, *Optimizing Receiver Performance Using Harm Claim Thresholds* (University of Colorado at Boulder Law School paper, 2013).
[20] *See* J. Pierre De Vries, *Optimizing Receiver Performance Using Harm Claim Thresholds* (University of Colorado at Boulder Law School paper, 2013).
[21] Michael A. Heller, *The Tragedy of the Anticommons: Property in the Transition from Marx to Markets*, 111 HARV. L. REV. 621 (1998); MICHAEL HELLER, THE GRIDLOCK ECONOMY (2008).
[22] James M. Buchanan & Yong J. Yoon, *Symmetric Tragedies, Commons and Anticommons*, 43 J. L. & ECON. 1 (2000).
[23] Lee Anne Fennell, *Common Interest Tragedies*, 98 NW. L. REV. 907 (2004).

robust opportunities for wireless technologies in the 21st Century requires an understanding of this paradigm, its application to current regulatory quagmires, its solution via observed regulatory successes, and strategies for reform. While tragedy occurred in the LightSquared Debacle, it is possible to transition administrative spectrum use rules towards effective, economically nimble rights allowing consumers, carriers, investors, technologists, and entrepreneurs to cooperate for mutual advantage in creating and operating advanced wireless networks. Such positive outcomes are observable; it is essential to understand how these contrasting results are achieved by policy makers.

In this article we explore the LightSquared-GPS conflict and identify the circumstances creating the regulatory commons. Given that interference effects are symmetric in nature, we explain why a focus on technology specifications is misplaced; proper rights definition will do more to maximize production from spectrum assets. We show that, because LightSquared and its *L Band neighbors* had expanded rights and the ability to bargain, the firm overcame serious interference with immediately adjacent rivals -- parties with more intense "technical" interference issues to overcome than those separated across bands. We then describe how terrestrial mobile license (called CMRS, for commercial mobile radio services) are liberally defined to approximate private property, and how these de facto spectrum ownership rights facilitate cooperative resolution of interference disputes. In LightSquared's dealings with satellite (and L Band) licensee Inmarsat, as with CMRS licensees' transactions, legal rights are defined so as to *accommodate market reallocations*. These examples suggest a policy framework to optimize wireless market productivity, avoiding LightSquared debacles in the future.

II. LIGHTSQUARED, LTE, AND GPS RECEIVERS

Under the Radio Act of 1927, government manages frequency access, restricting specific wireless deployments so as to pre-empt "harmful interference."[24] However, as Ronald Coase pointed out long ago, the problem is not one-way, but is symmetric.[25] The excluded activities have value, and suppressing them in order to protect others carries a cost to society. Put differently, rules to mitigate "harmful interference" simultaneously create "harmful interference" via lost output.

The social optimum is achieved via the mix of services that entail the highest total output (equivalently, the smallest "interference loss"). Regulators, however, do not internalize the costs or benefits associated with the relevant options and have strong incentives to remedy conflicts by avoiding controversy; this strategy is typically achieved by placating influential incumbents. The general result is widely observed: vast spectrum is overly restricted, practically unused. Productive wireless services, more valuable by

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[24] *See* Thomas W. Hazlett, *The Rationality of U.S. Regulation of the Broadcast Spectrum*, 33 J. L. & Econ. 133 (1990); Thomas W. Hazlett, *The Wireless Craze, the Unlimited Bandwidth Myth, the Spectrum Auction Faux Pas, and the Punchline to Ronald Coase's 'Big Joke': An Essay on Airwave Allocation Policy*, 15 HARV. J. L. & TECH. 335 (2001); Thomas W. Hazlett & Sarah Oh, *Exactitude v. Economics: Radio Spectrum and the 'Harmful Interference' Conundrum*, BERK. TECH. L. J. (forthcoming 2013).

[25] R.H. Coase, *The Federal Communications Commission*, 2 J. L. & ECON. 1 (1959).

orders of magnitude than the services "protected," are pre-empted. Regulators themselves cite exactly this outcome, expressing frustration over the system's inability to shift bandwidth from under-used employments to emerging wireless applications of far greater social significance.[26]

A regulatory commons occurs here because of the nature of the rights granted to, or withheld from, licensees. By authorizing the use of millions of GPS devices in the spectrum adjacent to the L Band, the FCC virtually ensured that future attempts to reallocate spectrum in this frequency neighborhood would prove contentious and difficult.

A. Conflict on the L Band-GPS Band Border

The dispute over the new LightSquared 4G network was not triggered by LTE emissions that would spill into the GPS band, but by the simple fact that the quiet L Band – hosting virtually no traffic, for very few subscribers, under satellite-only rules – would become much noisier when busy serving millions of terrestrial mobile voice and broadband data subscribers. Many GPS receivers have been built to analyze not just signals emitted in the authorized GPS band but signals traveling through the adjacent L Band. As Julius Knapp, chief of the FCC Office of Engineering and Technology, stated in congressional testimony, "In effect, we discovered that some GPS legacy equipment effectively treats the GPS spectrum and the L-Band spectrum as one band."[27] These emissions are an informational bonus that GPS radios use to fine-tune their locational estimates for objects or addresses. With greatly increased traffic in the L Band, as per the deployment of LightSquared's LTE network, this bonus would be lost and the service supplied by certain GPS receivers diminished.

The GPS market can be broadly grouped into two categories. In the mass market GPS receiver segment there exist tens of millions of GPS receivers in smartphones, automobiles, and GPS radios (produced by companies like Garmin or Tom Tom). These

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[26] FCC, NATIONAL BROADBAND PLAN 78 (2010).

> The current spectrum policy framework sometimes impedes the free flow of spectrum to its most highly valued uses . . . . In several instances, [the NTIA and FCC] assign large quantities of spectrum to specific uses, sometimes tied to specific technologies. . . . [B]ecause mission needs and technologies evolve, there must be a public review process to ensure that decisions about federal and non-federal use that may have worked in the past can be revisited over time. . . . In the case of commercial spectrum, the failure to revisit historical allocations can leave spectrum handcuffed to particular use cases and outmoded services, and less valuable and less transferable to innovators who seek to use it for new services.

Id. at 79. PCAST, REPORT TO THE PRESIDENT: REALIZING THE FULL POTENTIAL OF GOVERNMENT-HELD SPECTRUM TO SPUR ECONOMIC GROWTH 16 (2012) ("[W]e have created a fragmented partitioning of spectrum that has led to artificial scarcity and constraints on future uses. Because of this history, legacy spectrum assignments remain overly restrictive . . . .").

[27] Joint Written Statement of Julius P. Knapp & Mindel De La Torre 4 (Sept. 21, 2012), testimony before the U.S. House of Representatives, Energy and Commerce Committee, Oversight and Investigations Subcommittee.

applications are not terribly sensitive to small changes in accuracy; a left turn will not be missed due to a six-inch mapping difference.[28] So the cost of "L Band interference" would not likely be significant even absent mitigation techniques. In addition, there are approaches available to reduce device impacts to the level of imperceptibility. For instance, LightSquared offered to use only the lower half of the L Band, those frequencies located furthest (in frequency space) from the GPS Band, for a period of several years.[29] Then, as the LTE network scaled up in size, the additional 20 MHz closest to the GPS band would be deployed. This temporal lag would allow a new generation of GPS radios to be deployed, and these radios would include filters that eliminate noise from the L Band. In general, the small *cost to GPS users* would be more than compensated by the availability of an additional nationwide broadband network delivering *benefits to GPS users*, via increased market competition and enhanced bandwidth for mobile high-speed data service.

The second category consists of high-precision GPS devices. Parties selling or depending on such receivers were the primary source of political opposition to L Band LTE. This category involves a far smaller number of receivers, but includes those installed in mission-critical crash-avoidance systems on passenger airliners and self-guided steering mechanisms on tractors and other farm equipment that are accurate to the millimeter.[30] LightSquared estimated that there were 500,000 such devices[31]; the Coalition to Save GPS[32] argued that there are 750,000 to one million.[33]

To alleviate the most pressing concerns, LightSquared offered to replace government GPS units, spending up to $50 million.[34] The GPS parties claimed that that was clearly insufficient to mitigate the potential damage. The Federal Aviation Administration (FAA) released a study in 2011 that estimated the FAA's retrofit costs alone to be drastically higher – about $6 billion.[35] In addition, the FAA also estimated that adjusting its forthcoming NextGen air traffic control system[36] for L Band LTE

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[28] Consumer GPS devices are typically accurate to within 10 to 50 feet. GPS Basics, *How accurate is GPS?* (last visited February 20, 2013); *see also* Kevin Fitchard, *Analysis: Sorting out the LightSquared GPS interference mess*, CONNECTED PLANET (July, 18, 2011). The NTIA was ambiguous about whether using the lower 10 MHz would affect consumer GPS devices. *See* NTIA, Letter from Lawrence E. Strickling to Chairman Julius Genachowski 4 (Feb. 14, 2012).

[29] NTIA, Letter from Lawrence E. Strickling to Chairman Julius Genachowski 2 (Feb. 14, 2012).

[30] Kevin Fitchard, *Analysis: Sorting out the LightSquared GPS interference mess*, CONNECTED PLANET, (July, 18, 2011).

[31] Kevin Fitchard, *LightSquared, GPS industry spar over proposed interference fix*, CONNECTED PLANET (Oct. 14, 2011).

[32] Over 70 companies or trade associations are listed as members on the Coalition's website: Coalition to Save Our GPS, Coalition Members. They include UPS, Tom Tom, Southwest Airlines, FEMA, Garmin, John Deere & Co., Caterpillar, the National Association of Manufacturers, Delta, Fed Ex, Aircraft Owners and Pilots Association and the American Rental Car Association.

[33] Kevin Fitchard, *LightSquared, GPS industry spar over proposed interference fix*, CONNECTED PLANET (Oct. 14, 2011).

[34] LightSquared, *Statement of Jeff Carlisle*, Press Release (Oct. 27, 2011).

[35] FAA, *LightSquared Aviation Impacts* 6, Press Release (July 12, 2011).

[36] NextGen is a multibillion dollar upgrade to navigation systems on airlines, largely replacing radar-based systems with more precise GPS-based systems. Ashley Halsey III, *FAA to equip some JetBlue planes with*

conflicts would lead to 800 deaths over ten years and raise NextGen costs by $60 billion.[37]

Opponents of the LTE network included not only the FAA but the U.S. Department of Defense and a wide array of other parties with investments, products or operations in the GPS Band.[38] The Coalition to Save Our GPS was not bashful about stating its expected cost of mitigating interference from LTE use of the L Band. The organization summed the costs – just to government agencies -- at an astounding $245 billion.[39]

The large sum GPS groups estimated massively over-states the social cost of L Band LTE network interference. In the political arena, interested parties have strong incentives to emphasize the negative consequences of policies they oppose. The FAA's cost estimate for the NextGen delay, for example, implausibly exceeds the market capitalization of the entire U.S. passenger airline service industry[40] We also know these estimates are excessive because when the Coalition to Save Our GPS opposed the LightSquared's grant of ATC authority, they estimated that the new licenses permitting LightSquared to provide LTE were worth $10 billion in total.[41]

Simple Coasian analysis establishes this valuation as a cap on costs to GPS users. In his famous 1960 essay, "The Problem of Social Cost,"[42] Ronald Coase explained that the cost of any "harmful effect" is the loss in output it incurs. That loss, in turn, is bounded by the most efficient (least costly) mitigation technology. In this instance, the Coalition defines the upper limit of the cost of LTE interference to GPS as $10 billion. Were the costs of LTE interference above that amount, the mobile licenses could be purchased by affected GPS parties and the spectrum held vacant, eliminating the burden.

NextGen GPS technology, WASH. POST (Feb. 3, 2011). The FAA cost estimates arise from re-planning the GPS systems and infrastructure investments, which total $17 billion. It is not clear to us, in the FAA's letter to the FCC, where the remaining $42 billion in costs arise. *See* FAA, *LightSquared Aviation Impacts* 6, Press Release (July 12, 2011).

[37] FAA, *LightSquared Aviation Impacts* 6, Press Release (July 12, 2011).

[38] See note __, infra.

[39] Coalition to Save Our GPS, *Sampling of Departments and Agencies Shows $245 Billion Potential LightSquared Impacts on GPS in Federal Government Uses Alone*, Press Release (Oct. 27, 2011).

[40] In early 2013, the estimated market cap of the industry was around $50 billion. Delta-Northwest Air Lines - $11.66 billion; Southwest-AirTran Airlines - $8.55 billion; United-Continental Air Lines - $8.79 billion; American Airlines - $8.00 billion; US Airways - $2.20 billion; JetBlue Airways - $1.72 billion; Alaska Airlines – $3.57 billion; Spirit Airlines - $1.40 billion; SkyWest-ExpressJet - $0.71 billion. Source: Google Finance and Yahoo! Finance (Feb. 21, 2013). These airlines represent nearly 90% of market share (domestic revenue passenger miles). Source: Research and Innovative Technology Administration, Bureau of Transportation Statistics.

[41] Coalition to Save Our GPS, *LightSquared Did Not Pay for and Does Not Have a "Legal Right" to Build a Nationwide Terrestrial Network in the MSS Band* 3, Press Release (Oct. 27, 2011) ("If allowed to go forward, LightSquared gets to pocket the $10 billion increase in spectrum value that would result.") (citing a Brattle Group study of spectrum valuation).

[42] R. H. Coase, *The Problem of Social Cost*, 3 J. L. & Econ. 1 (1960).

Of course, the Coalition to Save GPS did not present its estimate of the ATC licenses as bounding the costs of interference, but to support its assertion that liberalization of LightSquared's satellite licenses extended an unjustifiable windfall:

> All in all, LightSquared's proposal represents a new low in financial engineering at the expense of the U.S. taxpayer. Never before has a single company tried to gain so much from our national spectrum resources and pay so little for the collateral damage caused by its plans.[43]

The outrage is ironic. The GPS Coalition was aiming to have a $10 billion windfall not extinguished – by auction to the high bidder – but transferred to GPS interests in the form of an FCC license cancellation. That transfer is what they claimed would best protect their economic interests. In the event, regulators obliged them, leading one to muse that "never before has a single [industry] tried to gain so much from our national spectrum resources and pay so little for the collateral damage caused by its plans." This collateral damage created no more than $10 billion in social gain, and yet caused easily more than $100 billion in social losses by pre-empting the creation of new LTE band.[44] The losses so dominate the gains that it is possible, even likely, that the welfare of most constituent members of the Coalition to Save Our GPS was adversely impacted. The gains from additional cellphone rivalry and mobile data network capacity would have reduced prices and expanded opportunities for wireless applications. Excluding this beneficial outcome outweighed any plausible gains from reduced interference costs for the vast bulk of GPS users.

B. The Nature of a Regulatory Commons

One way to protect GPS is to simply banish L Band LTE. Existing satellite phone services use very little of the total capacity of the L Band, which is why LightSquared attempted to exploit this unused capacity and why, without LightSquared's LTE network, the L Band would continue to be quiet and unassuming. With so little satellite phone usage, GPS receivers may continue to listen in the L Band to (marginally) improve their satellite reception.

The relative quiet signals the generation of little social value. The satellite telephone market has proven an economic graveyard, carriers declaring bankruptcy, one after the next -- Irridium,[45] Teledesic,[46] and Globalstar[47] -- among them. So long as the L Band is regulated under rules not allowing for popular, profitable services, it will

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[43] Kevin Fitchard, *LightSquared is jilting taxpayers out of billions, GPS industry claims*, CONNECTED PLANET (Oct. 27, 2011).
[44] See discussion in the next sub-section.
[45] Arik Hesseldahl, *The Return Of Iridium*, FORBES (Nov. 30, 2011).
[46] Sharon Pian Chan, *The birth and demise of an idea: Teledesic's 'Internet in the sky'*, SEATTLE TIMES, (Oct. 7, 2002).
[47] Barnaby J. Feder, Globalstar, *Bankrupt Satellite Company, to Be Sold for $55 Million*, N.Y. TIMES (Jan. 16, 2003).

continue to be an excellent buffer for GPS, much like living next door to a vacant lot affords a home owner extra parking.

But the L Band is an exceptionally expensive parking lot. In choosing to resolve the border dispute between LightSquared (and its future customers) and GPS users by killing LightSquared's LTE network, the Commission "interfered" with one set of wireless opportunities in order to protect another. It is impossible to know exactly how to quantify the costs and benefits in such a situation. This is the central problem in central planning of spectrum (or other) markets: prices are not available and the offers from willing partners in market transactions -- which reveal demand and supply information in standard economic exchanges -- are replaced by bureaucratic edicts.

The best publicly available information, however, supports the claim that the decision to kill the LTE network was -- by orders of magnitude -- a net loser for society. LightSquared estimated that its network using 40 MHz L Band would generate about $120 billion (present value) in consumer surplus.[48] These projections could be dismissed as biased, except that independent valuations of mobile radio spectrum in the U.S. yield higher forecasts – about $200 billion in social welfare (consumer and producer surplus).[49] These benefits from permitting LTE dominate the cost of fixing whatever problems were alleged to occur with GPS receivers, estimated at about $10 billion by the opponents themselves.

An objection may be raised: that the GPS interests -- which are numerous, use unlicensed radios, and have non-exclusive rights[50] -- are unable, in practice, to make a serious offer to acquire the L band licenses. Suppose, as a thought experiment, that Delta, Fed Ex, and UPS (three members of the coalition) were highly motivated to protect their GPS receivers from degradation and managed to raise the capital to buy the licenses for $10 billion. These parties could then leave the band as is, excluding terrestrial mobile traffic. This is the acquisition the FCC provided, but without charge to the Coalition.

This objection reveals part of the fundamental issue. The barrier to purchasing the adjacent spectrum for protection is the "free rider problem." The investment by the three firms would silence the source of interference for all the users of the GPS band, not just Delta, Fed Ex and UPS. The benefits constitute a non-excludable public good. Hence, it is likely that the three partners would not finance such a purchase. The capital actually invested would produce less than the optimal level of protection.

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[48] *See* Daniel Fisher, *What's Falcone's $4 Billion Gamble on LightSquared Worth Now?*, FORBES (May 1, 2012) (citing an economist's estimate that the LightSquared spectrum was worth approximately $12 billion and the consumer value around $120 billion).

[49] This is based on analogizing the 40 MHz of L Band spectrum to 30 MHz of generic mobile spectrum, estimated to produce annual social welfare gains of over $10 billion. The annual flow is discounted as a perpetuity at a real discount rate equal to five percent to produce a present value. This employs a model calibrated on international mobile market data to value the impact of additional bandwidth on prices and voice minutes (using U.S. data for the year 2003). *See* Thomas W. Hazlett & Roberto E. Muñoz, *A Welfare Analysis of Spectrum Allocation Policies*, 40 RAND J. ECON. 424, 435-36 (2009).

[50] *See* 47 C.F.R. § 15.5(b); 47 C.F.R. § 25.131.

Switching from thought experiment to real-world conditions, we see the character of the regulatory commons. A cooperative venture to buy "interference protection" via L Band ATC licenses is a transactional nightmare. GPS interests are permitted to use the GPS band -- and, implicitly, the L band next door -- not via the grant of de facto ownership rights but via specific use rights.[51] The "unlicensed spectrum" is governed by technical and behavioral rules (including power limits) established by regulators; they are non-exclusive and distributed to millions of disparate parties. Moreover, the GPS Band is widely allocated for uses by government agencies. These institutions are prohibited from reassigning rights in secondary market transactions.[52]

The regulatory commons results in the pre-emption of Coasian bargaining. This outcome is often referenced as "market failure," where positive-sum deals cannot be realized due to prohibitive transaction costs. But this outcome is conditional on the legal regime. Specifically, the creation and distribution of fragmented, incomplete, and non-exclusive GPS Band use rights by the FCC prevented bargaining -- a "non-market failure."

It is noteworthy that the dispute between LightSquared and GPS interests was not caused by insufficient specificity in interference contours, a common theme in the spectrum policy literature.[53] The rules were actually clear that LightSquared's LTE network was not to distribute out-of-band emissions above specified levels, and that the unlicensed devices in the GPS band would have to accept whatever interference licensed devices in adjacent bands might inflict.[54] The FCC simply chose to over-rule these regulations on "public interest" grounds, which the Communications Act of 1934 generally allows it to do.[55]

Moreover, the remedy imposed by regulators to the border dispute did not add technical sophistication to emission rules, but simply proscribes terrestrial mobile services in the L Band. While implementing the fix requested by GPS lobbyists, the FCC extinguished an arguable border incursion by slamming a blunt object against the spectrum allocation table -- removing no more than a $10 billion problem by eliminating a more than $100 billion gain. This did not remedy the "interference," but greatly expanded it.

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[51] *See* 47 C.F.R. § 15.5(b); 47 C.F.R. § 25.131.
[52] *See* 47 C.F.R. § 15.5(b); 47 C.F.R. § 25.131.
[53] *See* J. Pierre De Vries, *Optimizing Receiver Performance Using Harm Claim Thresholds,* (University of Colorado at Boulder Law School paper, 2013); Philip J. Weiser & Dale Hatfield, *Spectrum Policy Reform and the Next Frontier of Property Rights*, 15 GEO. MASON L. REV. 549 (2008).
[54] *See* 47 C.F.R. § 15.5(b); 47 C.F.R. 25.131. Garmin, for instance, stated the rule clearly in a 2006 technical document: "[Garmin GPS devices] must accept any interference received, including interference that may cause undesired operation." Garmin, *GPS 15H & 15L Technical Specifications, Revision D* 1 (2006). TomTom, likewise, declared its GPS devices to be in conformity with 47 C.F.R. Part 15. TomTom, *Declaration of Conformity* (2009).
[55] 47 U.S.C. § 309(a).

The unsatisfactory rights assigned to GPS users also made for a poor resolution process. The administrative procedures were opaque. The relevant questions concerning harmful interference were not presented side by side, and no objective quantification of the appropriate alternatives was put forward by spectrum allocators. This accommodated a decision in which policy makers -- regulators at the FCC, as well as powerful members in Congress and the Executive Branch -- could exercise political discretion.

This non-transparency derives from the endemic externality problem embedded in administrative allocation of a key resource such as radio spectrum. Economic choices -- in this case, resolving the conflict over how best to use the L Band -- are made by administrators who do not internalize the costs or benefits of their rulings. The lack of simple accounting is highly illustrative of the nature of the system. Decision-makers prefer not to make the alternatives explicit, as that would yield information for legal or political challenges, constraining their degrees of freedom.

As Blair Levin, formerly a top FCC policy official who headed the National Broadband Task Force in 2009-10, said:

> Through a complicated process—mostly out of the public eye—of K St. machinations, inter-agency battles, and congressional pressure, we as a country came to the unstated but clear conclusion that the GPS industry has a primary right to use the spectrum in the band owned by LightSquared.[56]

The passage is perfectly worded, except for the reference to "the band owned by LightSquared." As vividly demonstrated, the L Band was not owned by LightSquared, which owns only licenses authorizing particular activities. The FCC may extend or revoke such usage rights, according to "public interest, convenience or necessity." The owners of bankrupt LightSquared may have standing to challenge the administrative process in which its use rights were revoked as "arbitrary and capricious," but it has no claim for a violation of its property rights in radio spectrum.[57]

The LightSquared debacle does not owe its failure to the malfeasance of current FCC personnel, insufficiently clear spectrum use rights for L Band operations or GPS radios, or the villainy attributed to LightSquared's owners (including the political entrepreneur and private equity maven, Phil Falcone[58]). The essential source of misallocation is the creation of a regulatory commons: with spectrum use rights defined

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[56] Blair Levin, *Remarks to the Minority Media & Telecom Council*, MINORITY MEDIA & TELECOM COUNCIL (Mar. 8, 2012).

[57] 47 U.S.C. § 301 ("It is the purpose of this chapter, among other things, to maintain the control of the United States over all the channels of radio transmission; and to provide the use of such channels, but not the ownership thereof . . . ."). Licensees must waive "any claim to the use of any particular frequency or of the electromagnetic spectrum . . . because of previous use of the same." 47 U.S.C. § 304.

[58] Matt Levine, *Phil Falcone's Alleged Piggish Behavior Made Him Some Enemies*, DEALBREAKER (June 27, 2012); Azam Ahmed, *S.E.C. Files Civil Charges Against Falcone*, DEALBOOK (June 27, 2012).

in small, fragmentary, non-exclusive slices, economic reorganization, responding to new opportunities, is impossible due to prohibitive transaction costs.

III. THE BENEFICIAL ROLE OF SECONDARY MARKETS IN THE L BAND

Determining which party "caused" the interference is not a question competently pursued by government, and the "technical" metrics used to inform the question do not answer it. Indeed, the problems generated are symmetric, and *economic* in nature. Consider this description of the LightSquared-GPS dispute:

> Given that LightSquared is coloring within the lines, it claims that the GPS industry should be afforded no legal protection.
>
> Technically LightSquared is right, though interference was never a problem until LightSquared tried to rezone its L-band spectrum from satellite to terrestrial use. Even if the FCC were to agree, the commission is still in a tough spot since allowing LightSquared's network to go forward could jeopardize consumer, commercial and government navigation and location devices across the country.[59]

Yes, the regulatory choice is perfectly understandable. That is what makes the LightSquared Debacle *classic*, not *curious*. Some parties will have to adjust, with costly actions, to accommodate the new neighbors. But these costs cannot be avoided, and excluding the entrant does not minimize the expense. LightSquared's investors have already lost $4 billion; consumers in aggregate stand to lose orders of magnitude more. On the other hand, an expenditure of less than just $400 million would fix potential problems associated with the operation of its (now deterred) LTE network,[60] according to LightSquared's estimates.

LightSquared may be high or low, but the basic problem is not their math. It is that there is no GPS band owner, de jure or de facto, to bargain with. It lacks a responsible party -- one that can be paid to cooperate -- with which to trade. It has only a regulator, one pressured by both LightSquared and its GPS opponents. Two of the three sets of parties in this conflict resolution process, GPS interests and the regulatory authority, fail to internalize the costs and benefits resulting from the decision reached.[61]

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[59] Kevin Fitchard, *LightSquared to FCC: You Owe Us Spectrum*, GIGA OM (Mar. 16, 2012).

[60] There is reason to take LightSquared's estimates seriously. The firm sank large investments in a network that depended on GPS interference issues being resolved; it is clear that LightSquared believed that they could be resolved at reasonable cost. The $400 million estimate is calculated by adding filters to 500,000 "precision" GPS units at a cost of $800 each. This assumes the high-end, for each filter, of the stated price range ($300 to $800 each). Moreover, LightSquared's technology partner, Patron America, designed a filter that cost just $6. LightSquared committed to providing up to $50 million of such upgrades, at its expense, to protect government GPS devices from interference. Roger Cheng, *LightSquared's GPS Fix Could Cost Industry $400M*, CNET (Oct. 12, 2011).

[61] Charles Wolf, Jr. elaborates on problems generated by regulatory outcomes produced by decision-makers who do not internalize the costs and benefits of the choices made. Charles Wolf, Jr., *The Theory of Non-*

Unfortunately for LightSquared's owners, this makes their obstinancy free to indulge. Deterring large social gains for mobile wireless users presents no opportunity cost to GPS users or the FCC, as they are not in a position to capture gains from trade.

It is not a technical problem that has deterred LightSquared but the economic structure of the market as influenced by the legal regime. Consider that LightSquared had initially encountered severe *in-band interference* problems, but resolved them. Other licensees in the L Band -- notably, satellite service provider Inmarsat -- supplied important operations, including public safety, aviation, and national security applications.[62] The L Band channels allocated to these licenses were "interleaved" with those used by LightSquared (also supplying satellite services), creating potentially fatal interference challenges.[63]

While the L Band spectrum use rights had been fragmented, resulting in such costly boundaries, secondary markets were able to host transactions improving the initial allocations. Under the FCC's original band plan, licensed satellite carriers could not provide LTE or other non-satellite services, even if license restrictions were dropped, because the tiny bandwidth between "interleaved" borders crowded mobile traffic into uneconomically narrow lanes. To overcome this situation, LightSquared offered deals to its L Band rivals. Licenses were swapped and contiguous spectrum bands were created under the control of one company or another, LightSquared paying its neighbors to cooperate.[64] Border disputes were eliminated by eliminating borders.

Despite severe potential interference issues, a regulatory commons was avoided. With exclusive rights held by a small number of licensees, secondary trading led to a

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Market Failure: Framework for Implementation Analysis, 22 J.L. & ECON. 107 (1979); Wolf, MARKETS OR GOVERNMENTS (1993).

> Which failure is the greater, nonmarket or market, depends on whether the supply distortions created by internalities in nonmarket output are larger or smaller than the demand distortions created by externalities in market output.

Charles Wolf, Jr., *The Theory of Non-Market Failure: Framework for Implementation Analysis*, 22 J.L. & ECON. 107, 117-18 (1979).

[62] In 2004, before providing ATC services, Inmarsat had approximately 300,000 terminals deployed worldwide and delivered voice, fax, intranet, and Internet to land-based and maritime users. *Inmarsat to Seek ATC License*, PR NEWSWIRE (Feb. 15, 2006). *See* Jonathan Norris, *Inmarsat super-charges its mobile satellite services business*, APEX EDITOR'S BLOG (June 23, 2012) (describing Inmarsat's MSS applications).

[63] FCC, In the Matter of Mobile Satellite Ventures Subsidiary LLC; Application for Authority to Launch and Operate an L-Band Mobile-Satellite Service Satellite at 101 degrees W.L., DA 05-1492, *Order and Authorization*, 20 FCC Rcd 9752, 9765-66 (2005).

[64] Sarah Young & Paul Sandle, *Inmarsat's LightSquared Deal Activated*, REUTERS UK (Aug. 18, 2010) ("[Inmarsat] said the agreement would enable the companies to carve up their satellite spectrum over North America more efficiently"), citing a pay schedule of $81.25 million as an initial payment, with $337.5 million over three years, and $115 million per year in phase two, with the initial agreement signed in 2007 but activated in 2010.

spectrum reorganization in 2007.[65] According to the FCC, this process was critical. "Next generation broadband systems require large, contiguous blocks of spectrum . . . . [M]uch of the L-band spectrum will not be suitable for broadband without such coordination."[66] "Harmful interference" that blocked the emergence of an LTE network was remedied. By early 2012, the payments from LightSquared to Inmarsat had grown to $490 million.[67] These payments put Humpty Dumpty back together again:

> LightSquared is making significant efforts to rationalize narrow, interleaved bands of L-band spectrum, held by several international operators, into contiguous blocks that will support next-generation broadband technologies for both mobile satellite and terrestrial use . . . . The Commission has recognized that these types of operator to operator arrangements, especially in the L-band, should be encouraged and are preferable to "regulations based largely on hypothetical cases."[68]

In truth, the private agreements also deal with "hypothetical cases." Their real distinction is that they incorporate superior information and generate improved incentives for decision-makers. The FCC implicitly recognizes that the private ordering – where parties are rewarded for making better estimates and executing more efficient deals – regularly outperforms rules developed by those with no financial stake in the outcome.

With the licensees in the L Band, the FCC did not test radios, seek more clarity of "harmful interference," or determine what reliability level Inmarsat's customers would receive due to potential "harmful interference" from LightSquared's operations. They trusted the parties to make efficient choices with respect to these concerns. It is a wise approach, as the parties to the bargain have strong incentives to propose bargains generating gains for all.

Not so, however, with the rights distributed in the GPS Band. The parties alleging LightSquared's deleterious impact on GPS service are numerous, do not possess exclusive rights, and are often non-profit enterprises. Delaying or deterring productive wireless applications supplied by others does not appear to result in an opportunity cost to them. This constitutes a perfect storm for a regulatory commons. The resulting tragedy owes not to issues that can be decided on the basis of engineering data. As the LightSquared tragedy played out, an insightful news report summarized the technical information gleaned from government-conducted "harmful interference" tests:

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[65] LightSquared, *LightSquared Delivers Notice To Inmarsat Triggering Re-Banding Of L-Band Radio Spectrum In North America*, Press Release (Aug. 18, 2010).

[66] FCC, In the Matter of LightSquared Subsidiary LLC; Request for Modification of its Authority for an Ancillary Terrestrial Component, Order and Authorization, SAT-MOD-20101118-00239, 26 FCC Rcd 566, 569 (2011).

[67] FCC, In the Matter of LightSquared Subsidiary LLC; Request for Modification of its Authority for an Ancillary Terrestrial Component, Comments of Jeffrey Carlisle 8 (March 16, 2012).

[68] FCC, In the Matter of LightSquared Subsidiary LLC; Request for Modification of its Authority for an Ancillary Terrestrial Component, Order and Authorization, SAT-MOD-20101118-00239, 26 FCC Rcd 566, 581 (2011) (footnote omitted).

> For a purportedly 'scientific' report, the technical working group's interference study is extremely self-contradictory. LightSquared and the GPS industry reached entirely different conclusions in many of the report's focus areas even though both sides were relying on the exact same data and the exact same methodology.
>
> "It was clear there were very different interpretations of the data from the GPS group and from LightSquared," Spirent's Butler said. "What it came down to was the definition of harmful interference. The test methodology was pretty well worked out. We got good data. But without a meaningful common definition for interference, both sides reached different conclusions."[69]

Indeed, technological information will not answer whether 1dB loss in the signal to noise ratio (C/N_0) is the correct standard to use -- or 6dB. The former allows for more radiated energy to impact a radio receiver under a "no harm, no foul" assumption, the latter less. The choice between the different standards constituted perhaps the key determination in the entire matter. The NTIA choose 1dB as the standard, despite vigorous protestation from LightSquared that a 1dB loss had "little impact" and that "it is well understood that 1dB loss of C/N_0 is a very small fraction of the link margin that GPS receivers carry."[70] The "correct" amount of signal to noise is not a technical matter but an economic choice: how much is a tighter protective shield is worth, relative to its cost? The government's choice was the loss of a nationwide wireless network.

IV. LIBERAL RIGHTS ASSIGNMENTS MITIGATE THE REGULATORY COMMONS FOR CMRS LICENSEES

The conventional wisdom has built up in the U.S. that spectrum is very difficult to define and that interference conflicts are endemic.[71] But this view is highly misleading, a product of the manner in which certain conflicts are funneled through a political process. When appropriate spectrum use rights are in place, the contentiousness of border disputes typically dissolves. Hence, incentive structures created by FCC spectrum rights regimes support – or sabotage – efficient market reconfigurations. What we learn is that it is neither possible nor necessary to fully define spectrum contours ex ante; that some spillovers are efficient; and that optimal interference levels are quickly identified when incentives are properly aligned.[72]

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[69] Kevin Fitchard, *Sorting Out the Light-Squared Interference Mess*, CONNECTED PLANET (July 18, 2011).. Spirent is a firm that designs and tests wireless equipment.

[70] FCC, In the Matter of LightSquared Subsidiary LLC; Request for Modification of its Authority for an Ancillary Terrestrial Component: Comments of Jeffrey Carlisle A-41 (March 16, 2012).

[71] Philip J. Weiser & Dale Hatfield, *Spectrum Policy Reform and the Next Frontier of Property Rights*, 15 GEO. MASON L. REV. 549 (2008).

[72] [72] Charla M. Rath, *Defining Radio Rights: Theory and Practice*, 9 J. ON TELECOMM. & HIGH TECH L. 528, 530 (2011).

LightSquared's successful rationalization of the L Band is not unique. We have seen similar processes in several other markets, most notably with respect to CMRS allocations. When spectrum use rights have been distributed to responsible economic agents in the market, conflicts tend to be resolved – just as LightSquared was able to "clean up" the L Band through private contract. LightSquared's plans faltered in a cross-border dispute where it faced holders of non-exclusive rights, including public agencies unable to participate in secondary markets.

CMRS markets exhibit organizational efficiencies that arise when licensees are awarded broad, flexible rights to exclusively control a defined radio spectrum space. Operators are awarded CMRS licenses, a regulatory category that subsumes cellular, PCS (Personal Communications Services), AWS (Advanced Wireless Services), SMR (Specialized Mobile Radio), and 700 MHz allocations. In such licenses, the FCC delegates decision making over services, technologies, business models and network architecture to licensees, effectively permitting market allocation of the bandwidth.

Communications scholars Dale Hatfield and Phil Weiser concede the economic success realized in the operation of these wireless markets. But they argue that the de facto property rights held by mobile operators are not the basis of this success. Instead, they cite "the technical characteristics of PCS services" as uniquely favorable for limiting "harmful interference" claims. Mobile operators serve "large geographic areas" and are "cellularized," an architecture that generally lowers emission levels (say, compared to television broadcasting), making it easier to limit cross-border spillovers. Additionally, markets are served by "stable, 'repeat players'" with "considerable incentives for cooperative behavior."[73] Engineering professor Charles Jackson agrees, adding that PCS operators also enjoy greater autonomy over airwaves because they control both receivers and transmitters in the frequencies they use.[74]

These factors do help explain how CMRS licenses work, but inexorably lead to the conclusion that the nature of the liberal rights granted responsible economic agents – not special circumstances determined exogenously -- are key to producing the favorable outcomes seen.

We begin with the latter point by Jackson. The nature of the CMRS authorization

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> Licensees also deal with thousands of instances of interference from unauthorized operations each year. Again, licensees' efforts to resolve these issues are very much local and generally do not involve the FCC. If we can locate the source of harmful interference, we can often work with the owner of the property or transmitter to address the problem . . . .

Id.

[73] Dale Hatfield & Phil Weiser, *Toward Property Rights in Spectrum: The Difficult Policy Choices Ahead* 17, Cato Institute Policy Analysis No. 575 (Aug. 17. 2006).

[74] As cited in in Linda Doyle & Tim Forde, *Towards a Fluid Spectrum Market for Exclusive Usage Rights*, in Proceedings of the IEEE International Symposium on New Frontiers in Dynamic Spectrum Access Networks (DySPAN'07), 620-632, 628 (April 2007).

is to cede choices over spectrum use in a given band to a given licensee. The licensee is then free to share access to the allocated bandwidth with others; indeed, this is the basic business model that makes CMRS licenses worth billions of dollars in the U.S. But how is this best done? With FCC allocations, exclusive rights are sometimes awarded; in other cases non-exclusive, overlapping use rights are authorized, as with unlicensed bands.

The incentive yielded by the broad scope of the CMRS rights is that the licensee optimizes the total value of services using the underlying spectrum. This creation of valuable services forms the pool of benefits from which the carrier obtains payment. In particular, the licensee constructs and operates networks, retaining control over spectrum and the receivers and transmitters. This vertical integration is dictated by efficiency concerns,[75] flowing from the licensee's incentive to optimize spectrum access. In CMRS networks, thousands or even millions of mobile devices are emitting and receiving signals -- exactly why such networks are built in the first place. Yet, such traffic creates endemic compatibility issues and potential interference. The emissions or downloads of any one user can negatively impact the cellphone performance of many others.

CMRS operators respond to such challenges in systematic ways, even as competitive innovations are continually introduced in the rivalry between platforms. First, carriers assiduously avoid splitting control over spectrum and network resources. Indeed, it is seen that, as Jackson says, "handsets are part of the network."[76] This drives not only integrated control of spectrum and infrastructure, but strong carrier coordination of what devices are permitted to use the network (setting standards, testing and certifying devices). Second, carriers employ prices to protect high-valued applications by excluding low-valued access. "Bandwidth hogs" are free to use networks, but they must pay for the privilege. With both equipment authorizations and pricing menus, carriers maximize by effectively coordinating access across all "transmitters" and "receivers."[77]

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[75] Licensees like Verizon or AT&T rely on markets to supply much of the mobile ecosystem, of course. The technology and infrastructure are developed by such firms as Qualcomm, Nokia, or Alcatel-Lucent; handsets by Apple, Samsung, Blackberry or Sony-Ericsson; application platforms by the Apple App Store, Google Play or Windows Store; and a virtually limitless array of edge providers – from Wikipedia to Ancestry.com to Twitter – supply content. That ownership of CMRS licenses is inevitably integrated with the ownership of the mobile network departs from this decentralized structure. In general, the carrier sinks considerable capital to construct and operate a mobile platform upon which an ecosystem may evolve, retaining control over both spectrum and core physical network infrastructure. Rival service providers and subscribers share these assets, but by purchasing bundled services (spectrum access plus network access) rather than "naked" spectrum or network elements. This structure allows the carrier to coordinate highly complementary inputs, mitigating transaction costs and strategic hold-up. *See* Benjamin Klein, Robert G. Crawford & Armen A. Alchian, *Vertical Integration, Appropriable Rents, and the Competitive Contracting Process*, 21 J. L. & ECON. 297 (Oct. 1978); Thomas W. Hazlett, David Teece & Leonard Waverman, *Walled Garden Rivalry: The Creation of Mobile Network Ecosystems*, George Mason University Law and Economics Research Paper Series 11-50 (2011).

[76] *See* Charles L. Jackson, *Wireless Handsets Are Part of the Network*, *in* In the Matter of Skype Communications S.A.R.L., Opposition of CTIA – The Wireless Association, RM-11361, Appendix C (2007).

[77] "We have already suggested that 'spectrum' consists of a licensee's right to send signals from a transmitter to a receiver at a specified power and frequency. A 'complete' bundle of property rights in

Third, mobile operators invest continually to upgrade technologies, expanding network functions and capacities. Cellular networks in the U.S. have advanced from 1G to 2G to 3G to 4G since mid-1990s without any government mandates to do so. Along the way, mobile carriers (also without mandate or directive) introduced whole new services such as texting, push email, and broadband access, hundreds of new devices (netbooks, tablets, and smartphones), and hundreds of thousands of mobile applications.[78] Each network upgrade involves a delicate balancing act, protecting existing services and subscribers, while accommodating new, *potentially interfering* uses.

These improvements would, if directed by the FCC, constitute "spectrum reallocations." The fact that airwaves can be deployed in new networks or used to support innovation services is a product of the liberal use rights extended in the CMRS license. Markets -- or, "secondary markets," since the initial FCC assignments are being rearranged by transactions between private firms -- are thus able to create new ownership structures. The outcome of this trading process *could be* extreme fragmentation resulting in the costly border disputes seen in so many wireless markets. But the for-profit firms holding liberal licenses avoid such wealth-dissipating tragedies. The observed market structures reflect this strategic interest in maintaining an optimal level of control -- far from total, as seen in the robust nature of the evolving, decentralized marketplace (see Figure 1), but designed to be sufficient to keep spectrum resources from being squandered.

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spectrum must include the ability to close off the output end of that conduit, not just to control the input end. The owners of the TransAlaska Pipeline, for example, would not be said to enjoy full property rights if they were free to pump oil in at the Prudhoe Bay head-end but not to control who takes oil out at the Valdez terminus. It would similarly be of little service for a DBS operator to carry a subscription programmer's material if parties other than the paying subscriber were free to demodulate the signal. The right to exclude is accordingly recognized by courts as 'one of the most essential sticks in the bundle of rights that are commonly characterized as property.'" Howard A. Shelanski & Peter W. Huber, *Administrative Creation of Property Rights to Radio Spectrum*, 41 J.L. & ECON 581, 584 (Oct., 1998). *See also* Linda Doyle & Tim Forde, *Towards a Fluid Spectrum Market for Exclusive Usage Rights*, in Proceedings of the IEEE International Symposium on New Frontiers in Dynamic Spectrum Access Networks, 628 (April 2007)..

[78] Alternatively, in broadcast television, where TV licensees do not control spectrum and TV receiver sets are unlicensed devices regulated by the FCC, vertical disintegration is mandated. Television networks, despite benefiting when their viewers receive clearer signals and improved content, have no pragmatic means – apart from government mandates -- of upgrading technology. The digital TV transition officially launched by the FCC in took over two decades (1987-2009) and – most importantly – kept spectrum bottled up in an outmoded delivery platform, terrestrial broadcasting, that costs society at least two orders of magnitude more than it delivers in economic gain. Thomas W. Hazlett, *Unleashing the DTV Band: A Proposal for an Overlay Auction, Comment to the FCC*, NBP Public Notice No. 26 (Dec. 18, 2009).

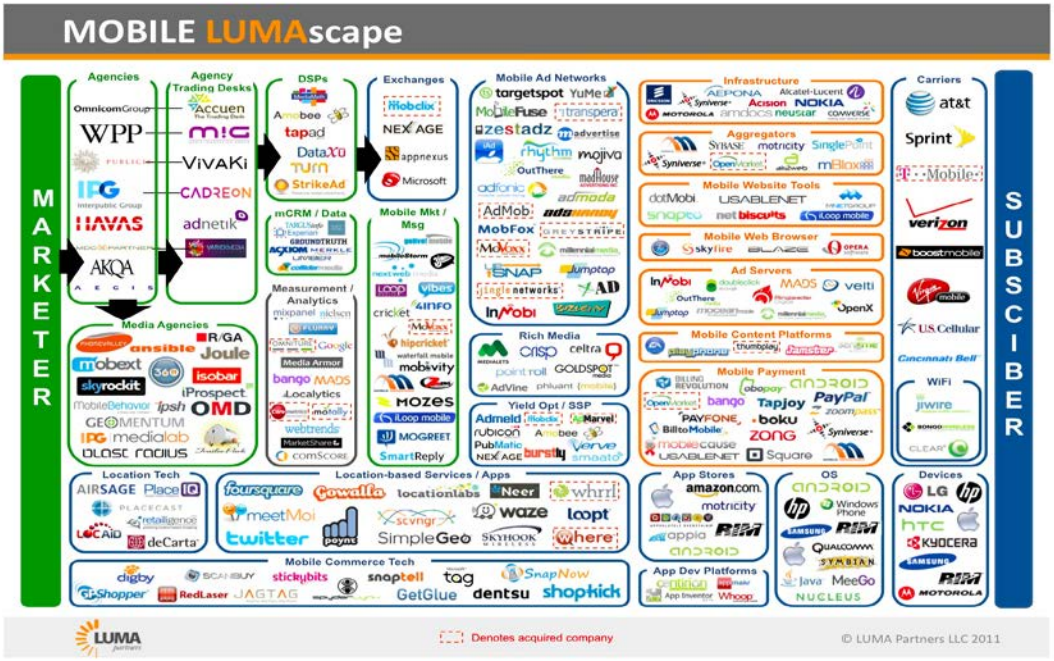

FIG. 1. STYLIZED STRUCTURE OF THE MOBILE ECOSYSTEM[79]

Hence, the large degree of integration observed in mobile markets is an endogenous outcome of a process triggered by the liberal spectrum rights. Rather than being dictated by the cellular technology, it is the result of rational choices made by properly incentivized economic agents. Indeed, this ownership structure is so central to the success of the market that it appears to be inseparable from the cellular technology itself, driving Hatfield, Weiser, Jackson, and others' confusion. The "large geographic areas" for CMRS coverage areas that Hatfield and Weiser cite as special circumstances, for example, are almost entirely a product of secondary market transactions, not regulatory fiat. U.S. regulators notoriously fragmented rights, in fact.[80] The total number of mobile licenses issued by the Federal Communications Commission easily exceeds 50,000.[81] All of which have been merged into four, fix, or six national wireless networks -- depending on how one counts -- through merger.

[79] This rendition was created by Luma Partners, a U.S. investment banking firm.

[80] Whereas countries in the European Union, for example routinely award national licenses, the FCC divvies America into 734 local franchise areas (for Cellular Market Areas, or CMAs) and 174 Economic Areas (EAs) for the primary license maps used. Together with the even more fragmented license rights issued in Specialized Mobile Radio (SMR) and then brought into the cellular market as per a 1990 liberalization.

[81] In July 2003, a count of mobile licenses totaled 51,597. Thomas W. Hazlett, *Is Federal Preemption Efficient in Cellular Phone Regulation?*, 56 FED. COMM. L. J. 155, 193 (2003). Since that time the FCC has held auctions for AWS, in which 1,087 licenses were sold (in 2006), and 700 MHz, in which 1,090 licenses were sold (in 2008). FCC Website, Summaries for Auction 66, Auction 73.

This merger process deserves special attention. The creation of thousands of CMRS licenses by U.S. regulators imposed substantial costs on the market due to the importance of economies of scale and scope in mobile networks.[82] In simple terms, 734 small cell-phone systems using a given swath of spectrum, but with different coverage areas,[83] have costs substantially higher than one cellular system using the same spectrum but with nationwide coverage. In economic terms, the adjacent networks are highly complementary assets, and combining them into common ownership better coordinates production, generating large efficiencies. Or, from the opposite perspective: to the extent that the regulatory license map is not adjusted by secondary market transactions, there would exist massive and pervasive "interference" between licensees, each of whom is blocking the scale economies that are possible to exploit.

This economic interference from excessive fragmentation translates directly into radio "interference." When allocations are intentionally de-concentrated by policy makers, extra borders are created in spectrum space. It is over the rules governing these borders that interference disputes are waged. A significant portion of the economies of scale that accrue from secondary market transactions of CMRS licenses, then, owe to the elimination of such spillovers. When firms sharing a contentious border combine, integrating assets under one owner, spillovers are eliminated; the new firm maximizes the total value of the combined spectrum.[84] In short, border disputes are eliminated by eliminating borders. But this useful process of rights aggregation via secondary market transactions can only occur when regulators have defined ownership so as to support such activity.

Another supposedly unique cause of harmony in CMRS cited by Hatfield and Weiser, cellularization, is an architectural choice made by licensees. One advantage of the approach is to allow lower power levels to be used in handsets, which need to send signals only to nearby base stations, enabling networks to "re-use" channels from cell to cell. To the degree that cellularization reduces spillovers, its adoption is again endogenous to the incentives yielded by the liberal license, not an artifact of the technology.

Indeed, where liberal licenses are lacking cellular systems have been involved in some of the bitterest and most intractable FCC interference disputes in history -- for example, the LightSquared debacle. LightSquared's ill-fated LTE network was cellular and its emissions well-behaved, conforming to border limits as set by the FCC. Another example involving low-power cellular emissions was the years-long Nextel-public safety dispute over the use of 800 MHz frequencies. This episode has been singled out by Hatfield and Weiser as illustrative of the failure of markets in handling spillover

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[82] Brokerage fees in cellular license transactions in just one year (1991) were estimated by the FCC to total about $190 million. FCC, *The FCC Report to Congress on Spectrum Auctions* 8, Wireless Telecommunications Bureau (Oct. 9, 1997).

[83] Two cellular licenses were issued (by lottery) in each of 734 local license areas, for example.

[84] This important point has been made for externalities generally in Harold Demsetz, *Ownership and the Externality Problem*, in Anderson & McChesney, eds., PROPERTY RIGHTS: COOPERATION, CONFLICT AND LAW 282 (2003).

problems.[85] First, this directly contradicts their claim that cellular technology yields harmony; the Nextel system accused of causing interference was a cellular network. Second, it is a fact that the dispute was a direct product of the fact that the public safety agencies complaining about radio interference were governmental entities unable to participate in secondary market transactions.

Third, the solution to the interference dispute, as implemented by the FCC, mimicked secondary market mergers. The Commission enacted a "spectrum swap" wherein Nextel traded cash ($4.8 billion) plus its licenses to access spectrum adjacent to police and fire department bands, in exchange for a CMRS license using bandwidth removed from its neighbors. The reason that such a transaction had to be imposed as a "spectrum swap" by regulators was that the parties Nextel had to transact with -- public safety organizations -- were barred by law from selling their licenses. It took the FCC essentially a decade to create a facsimile of this market process.[86]

Finally, consider cross-border disputes that remain, even after mergers have aggregated the vast majority of licenses and eliminating all but a handful of borders. As Weiser and Hatfield note, the interference between mobile operators is not an issue of regulatory concern, given that the "stable, repeat players" prefer to settle these issues privately. But "stable, repeat players" could not themselves avoid the Nextel and public safety conflict. Between CMRS licensees, in contrast, interference mitigation is pro forma. As Charla Rath, an executive with Verizon Wireless, describes it,

> Under current rules, licensees negotiate to extend rights into each others' licensed spectrum on a daily basis. These are not massive, onetime negotiations between companies, but involve hundreds of individual negotiations between companies' engineers who are tasked with the day-to-day operations of the network. [87]

The policy key to the observed harmony: "under current rules." These rules give (a) exclusive domain to profit-maximizing carriers over spectrum use, yielding incentives for optimization; and (b) yield flexibility to those licensees, allowing them to adjust operations so as to mitigate border incursions without seeking administrative waivers or otherwise engaging regulatory agents. In this environment, gains from trade are regularly effectuated, with efficient solutions to conflicts serving the interests of all. More to the

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[85] "[C]oordination and possible relocation costs—or other transaction costs (such as developing clear legal entitlements)—may be too formidable to be addressed through private market arrangements." Phil Weiser & Dale Hatfield, *Spectrum Policy Reform and the Next Frontier of Property Rights*, 15 GEO. MASON L. REV. 549, 573 (2008). For a recent case where the FCC stepped in to coordinate a relocation of a set of incumbent licensees to avoid adjacent channel interference, see FCC, Improving Public Safety in the 800 MHz Band, *Report and Order*, 19 FCC Rcd 21818 (2004).

[86] *See* Thomas W. Hazlett & Sarah Oh, *Exactitude v. Economics: Radio Spectrum and the 'Harmful Interference' Conundrum*, BERK. TECH. L. J. (forthcoming 2013).

[87] *See* Charla M. Rath, *Defining Radio Rights: Theory and Practice*, 9 J. TELECOMM. & HIGH TECH L. 528, 529 (2011) (citing 47 C.F.R. § 24.236) (permitting field strength agreements in PCS, AWS and 700 MHz); 47 C.F.R. § 27.55(a) (2008) (permitting private agreements in AWS 1 and 700 MHz); 47 C.F.R. § 22.912 (2003) (permitting cellular licensees to agree on service area boundary extensions).

point, running to regulators, which would replace such bargaining with FCC rulings, is seen as inefficient.

In a specific instance relayed to one of the authors by an engineering consultant, Nextel complained to Verizon, circa 2002, about interference it was receiving from the latter's base stations using 800 MHz (cellular) bands next door to frequencies allocated to Nextel's SMR licenses. While Verizon was complying with FCC rules, not technically creating impermissible "harmful interference," it nonetheless agreed to install new filters on its base stations. Nextel paid for the filters, and may have provided additional compensation.[88] Such settlements avoid regulatory overhead and are common within the wireless industry.[89] This is a product not of CMRS technologies, but of the assignment of efficient rights bundles to responsible economic agents who internalize the costs and benefits of engaging in contentious dispute resolution -- or avoiding it -- at the FCC.[90]

CMRS is exceptional, not because of any given technical or economic aspect of the service, but due to the expansive, flexible nature of the use rights awarded the licensee. These rights are distinct from the narrowly-specified use permits authorized in a traditional FCC wireless license, and -- like LightSquared was able to do in the L Band -- enable profit-seeking enterprises to merge, trade, partner, or otherwise create financial structures that bring the incentives of rival parties into alignment.

V. POLICY IMPLICATIONS AND CONCLUSION

LightSquared faced two challenges in turning virtually worthless "satellite spectrum" into highly valued "LTE spectrum." The first was that the satellite licenses they owned were allocated "interleaved" channels, mixed in with channels licensed to other satellite operators in the L Band. These narrow channels made the provision of profitable mass market mobile services quite impossible; modern cellular systems use much larger channels for efficient operations. While the total bandwidth available in the designated "satellite" L Band was sufficient to support such operations, the fragmented band plan imposed years previously by regulators prevented it.

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[88] This episode was relayed to author Thomas Hazlett by an RF engineer who had, during this period, served as a consultant to Nextel and, at other times, has worked at the FCC.

[89] Charla M. Rath, *Defining Radio Rights: Theory and Practice*, 9 J. ON TELECOMM. & HIGH TECH L. 528, 529 (2011).

[90] Cellular systems are themselves subject to tragedy of the regulatory commons when rights are held by regulators rather than responsible economic agents. The "harmful interference" problems associated with cellular systems turned into years-long logjams at the FCC. The first cellular allocation, in fact, took somewhere between 11 and 43 years, depending on how one establishes the end points. Cellular technology was developed at Bell Labs in 1946. In 1968 the FCC opened a formal proceeding to allocate spectrum for the service. In 1984-89 the Commission issued about 1,468 licenses, mostly by lottery, for each of the two systems it authorized across 734 CMAs. The FCC's National Broadband Plan summarized the regulatory delay as lasting from 1970 to 1981, or 11 years. *See* FCC, NATIONAL BROADBAND PLAN 79 (2010).

LightSquared (and its predecessors) dealt with this problem straightforwardly. LightSquared negotiated bargains with the other licensees, namely Inmarsat, and rationalized ownership rights. Putting the Humpty Dumpty L Band back into continuous spectrum blocks, necessary in order to deploy a competitive terrestrial mobile network, was expensive. But through license trades and monetary payments LightSquared reconfigured L Band spectrum into contiguous blocks -- one of which they controlled.

As they built and readied to deploy their new LTE network, however, an issue of cross-border interference arose. The highly fragmented and incomplete rights that GPS users had been awarded created a regulatory commons. In technical terms it was far less prohibitive than the issue of L band interference. LightSquared's LTE operations would not transmit over the ostensibly established border; the conflict arose because radios in the neighboring GPS band "listened in" to the L Band and would be potentially confused by rising noise levels there. Whatever the damage to the GPS services from LTE in-band interference, the dollar cost was dominated by an order of magnitude, or more, by the benefits to mobile wireless customers enjoying an additional nationwide broadband network to choose from.

No matter the modest scale of the actual problem, the political conflict proved intractable. Users of the GPS band possess non-exclusive use rights, using radios approved by the FCC under unlicensed device rules. Powerful interests with significant operations in the band, including the Federal Aviation Administration, are public agencies and are unable to participate in secondary market transactions. Bargaining broke down.

When so many parties use a resource, but none exercise actual control, a commons is said to exist.[91] In this instance, the GPS "commons" is protected by regulators, third party agents who do not internalize the costs or benefits of their actions. Rather, they are incentivized to craft rules that reflect political equilibria. Those equilibria, as seen throughout the history of FCC regulation, disproportionately favor incumbents and may impose large net costs on society. This is seen in symmetric evaluation of problem solving under alternative regimes. With the regulatory commons, under-allocation of spectrum, squandering valuable wireless services, is the norm.

Conversely, with flexible, exclusive spectrum rights, assigned to responsible economic agents, markets are able to efficiently structure ownership rights. Border disputes are largely eliminated via merger, eliminating the borders themselves, or modest adjustments to radios or network configurations. This performance, seen primarily by CMRS licensees but also in LightSquared's L Band rationalization, is so strikingly superior to the failures endemic in the regulatory commons that it is surprising that its policy implications are so widely misunderstood.

[91] In fact, this is loose terminology, in the sense that, were a group of owners actually vested with ownership rights, they would have incentives to organize their efforts so as to protect against resource dissipation. A corporation, a classic commonly owned resource, does this through extensive governance institutions.

Using regulatory forms already implemented, policy makers can strategically avoid meltdowns such as the LightSquared debacle by avoiding the impractical rights distributions that create them. While much damage has already been done over the past 85 years of allocation under a top-down administrative planning model, substantial improvements have been demonstrated, particularly in CMRS allocations, and can be more fully employed in other allocations, unleashing very large increments of consumer welfare.

Take government emergency radio services. Instead of giving thousands of public agencies (there are more than 100,000 wireless licenses awarded to local fire, police and EMT departments[92]) control over the use of specific frequency spaces, taking such spectrum out of any possible secondary market restructuring, such agencies can be funded to purchase radio services from commercial providers.[93] These contracts with providers could feature redundancy across networks and technologies; handsets that shift from terrestrial mobile base stations to back-up satellite service when a natural disaster knocks out local communications, have long been available. Important efficiencies are achieved by focusing on the price-quality package purchased; in particular, agencies can select among competitive service offerings, and have the very attractive option to share networks with commercial (non-emergency) subscribers, dramatically lowering the cost while raising the quality of network services. (Presumably, contracts would contain terms for prioritizing traffic; in emergency situations, public safety users would have first claim on bandwidth.) The present alternative locks in a given amount of spectrum and then directs agencies to construct their own network from there. It makes no more sense than shipping police departments specified quantities of auto parts, mandating that they use this much -- no more, no less, no different -- for the construction of police cars.

Spectrum is an input into an output. It is that output, wireless communication, that the government agency needs to consume. It is difficult to know, objectively and from outside an actual situation, how much of each ingredient is the right amount to use. It is impossible to know what will be the right amount (or type of spectrum) in the future. Better to let markets configure the inputs, and governments to buy the outputs. This will not cost taxpayers more, but less. Not only will the receipts from the sale (auction) of liberal licenses be substantial, the use of government resources will become more effective and efficient.

Consider, next, the allocation of unlicensed bandwidth. Such bands, like GPS, are managed by regulators, who establish rules of access. But regulators do not know how much an unlicensed band is worth to society relative to the alternative -- the same bandwidth allocated to liberal licenses, auctioned to the highest bidders. The information gleaned in the market, where resources go to those who value them most highly, is truncated when the FCC sets aside spectrum for unlicensed use. The decision to do so

[92] GAO, *Telecommunications: Actions Needed for Better Management of Public Safety Spectrum* 2, GAO 88-173 (1988).

[93] Funds could come from general revenues and those generated by wireless licensed auctions.

invariably turns into a battle between warring corporate factions, those who believe their business models will best prosper with one type of allocation or the other. Regulators materially benefit by being the locus of such tug-o-wars; they get to exercise their preferences, while mingling with those industry executives that they might like to work with during post-agency employment, enhancing their human capital. But the economic way to resolve such allocation questions is to let the opposing parties bid for unlicensed bands. FCC experts have elucidated this approach previously:

> Some special administrative provisions for low-powered devices may be efficient in a market system. However, in making decisions about the amount of spectrum allocated to unlicensed use, the government should face the opportunity cost of limiting or foreclosing other use . . . . Future expansion of dedicated spectrum for unlicensed use could be obtained through . . . a licensee . . . charg[ing] manufacturers a fee for the right to produce and market devices to operate in that band.[94]

Most fundamentally, transparency is valuable. It is lost in spectrum allocations that distribute use rights in fragmented parcels, withholding key rights from the market and thereby forcing all reallocations of frequency space to flow through regulators. Given that such costs can be mitigated or avoided, they should be accounted for in the initial allocations made by regulators.

The government, the public, and competing interests jockeying for policy should know what opportunity costs are associated with rival choices. Just as land is distributed to decentralized property owners, with governments then acquiring resources to supply public parks, spectrum allocated for unlicensed operations can be markedly improved by the use of – and constraints embedded within -- market prices. When choices are made to use given frequencies in one manner versus another, the prices made to secure that outcome reveal the value of the alternatives sacrificed. This crucial accounting is what is sacrificed in top-down allocations that effectively force bureaucrats to make trade-offs ill-informed by market data and heavily influenced by political pressure. Exhibit A: the LightSquared debacle.

Unlicensed bands are often, in fact, analogized to public parks.[95] But the implications of the analogy are the reverse. Land resources are not bottled up in case-by-case allocations, the state choosing between parks or other real estate deployments. Instead, resources are generally made available to the market via fee simple ownership rights. Trading then takes place, prices are revealed, and transactions divert resources into their most highly valued employments. These can and do include public parks -- with taxpayers, voters, interest groups and policy makers forced to confront the associated opportunity costs. This not only improves initial allocations, but removes the hidden costs of lock-in via regulatory commons.

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[94] Evan Kwerel & John Williams, *A Proposal for a Rapid Transition to Market Allocation of Spectrum* 7, 31, Federal Communications Commission, OPP Working Paper No. 38 (2002).

[95] FCC, SPECTRUM POLICY TASK FORCE REPORT 36 (Nov. 15, 2002).

Such costs are routinely ignored in the spectrum allocation process, which continues to create legal regimes -- such as the TV White Spaces proceeding, ongoing since 2002 and still mired in rulemakings and trials[96] -- that force the government to make allocation choices without the benefit of competitive spectrum valuations. Policy makers believe that certain business models, such as local area networks commonly supported in the use of unlicensed spectrum (as with wifi, cordless phones, or baby monitors) cannot be accommodated without government issuing non-exclusive spectrum use rights. They are mistaken in this. Not only can liberal licenses support local networks (where devices come 'plug 'n play' from the electronics vendor, no wide area network carrier needed), as suggested by FCC analysts themselves, the FCC has previously authorized band managers to help coordinate unlicensed users.[97]

Without the property rights necessary to utilize secondary markets, future opportunities for enhanced wireless communications will have less chance for success. When regulators consider alternative legal regimes in initial spectrum allocations, this is a vital -- if overlooked -- factor. The extraordinarily high social costs of just one tragedy of the regulatory commons, as demonstrated in the elimination of LightSquared's 4G network, reveal the magnitude of the error made when the costs of rights fragmentation are ignored by policy makers.

[96] Bill Ray, *'Google Maps' of US White Space spectrum goes LIVE Mountain view trials database now - before 16Mbps devices are EVERYWHERE...*, THE REGISTER (Mar. 3, 2013).

[97] As in the creation of a trade association, UTAM, to coordinate collective action by unlicensed device users in the unlicensed PCS band. *See* Kenneth R. Carter, *Policy Lessons from Person Communications Services: Licensed vs. Unlicensed*, 15 COMMLAW CONSPECTUS 93 (2007).