

# HOW TO THINK ABOUT DRONES



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## EXECUTIVE SUMMARY

Virtually every state in America has either passed legislation or is contemplating legislation to regulate drones—small unmanned aircraft with the capability

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of autonomous flight. The FAA Modernization and Reform Act of 2012 requirement for the integration of drones into the National Airspace System by 2015 has triggered a flurry of interest in the technology. Unfortunately, the current regulatory structure as defined by the Federal Aviation Administration poses a tremendous barrier to entry for drone-based businesses, and has placed the industry behind more drone-friendly countries like Japan and Australia, where unmanned aircraft have enjoyed approval for commercial use for years. State-based regulations might present an opportunity to improve the situation.

Drone regulations affect numerous constituencies. Included are hobbyists, drone-based entrepreneurs, civil liberty and privacy advocates, law

enforcement, and ordinary citizens concerned about the impact of this relatively new technology. Input from all these groups should be solicited in forming Colorado's drone laws.

Colorado should avoid knee-jerk attempts to ban drones altogether, based solely on civil liberties concerns or the potential for risk. Groups like the ACLU have established sound guidelines for drone use by law enforcement, guidelines that merit enthusiastic support. Drones offer potential economic benefits in areas such as agriculture, law enforcement, aerial imaging, and direct-to-customer delivery. In fact, this year the online retailer Amazon introduced its "Prime Air" plan to deliver packages to customers via drones. If concerns about civil liberties and privacy can be addressed, estimates for the market for drone-based services and economic benefits run into the billions over the next decade. Careful attention to privacy and civil liberties can lead to reaping the economic benefits.

Drone regulation should make extensive use of common-law property rights, tort law, and individual consent wherever possible. Any legislation that does emerge should emphasize clarity, fairness, and neutrality. Private drone users who choose to create wealth through private enterprise should be allowed to keep the rewards of their efforts, while still being held accountable and responsible for their actions. They should neither be subsidized due to the risk of failure, nor penalized if they succeed.

This Issue Paper offers suggestions on how to promote the benefits for private and public actors, while mitigating the risks drone use presents. The key recommendations are:

### 1. Remember the principles of good policy.

Good drone regulation should be clear and consistent. It should not bestow special privilege, but should apply equally to all. It should neither subsidize nor tax, it should be financially neutral, and it should promote benefits while mitigating risk. Finally, it should be reviewed periodically to keep up with a rapidly changing world, repealing outdated provisions and improving itself in response to evidence of how well it is working.

### 2. Give bottom-up approaches a chance to emerge before mandating top-down ones.

Private individuals and institutions offer a distributed, decentralized way to coordinate resource use and solve social problems. Such solutions take time and patience to emerge, but are worth waiting for. Any regulator should first ask: "Is law the best way to solve this problem?"

### 3. Solicit input from all stakeholders.

This includes drone entrepreneurs, civil liberty and privacy advocates, hobbyists, ordinary citizens, non-profit organizations, law enforcement, academic researchers, and regulatory agencies.

### 4. Use existing common law and property rights frameworks whenever possible.

Existing Colorado statutes should be reviewed to ensure that they can effectively address the

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use of drones in criminal activities, provide for compensation in the event that drones damage property, and so forth.

**5. Make sure law enforcement and state offices are prepared.** For example, judges who issue search warrants should be made aware of the implications of drone use by law enforcement. The Colorado Insurance Commissioner's office should understand the pivotal role insurance will play in the emerging drone-based sector of the economy.

**6. Avoid knee-jerk reactions to ban drones entirely, or to focus exclusively on safety.** Perfect safety is never achievable. Resources spent to obtain it are subject to the same laws of diminishing returns as with any other economic good. After all, automobiles are extremely dangerous to human lives, but banning them would be a terrible mistake. Instead we have mechanisms in place involving negligence, compensation, drunk driving, and so forth that enable us to live with the consequences while still enjoying the benefits of personal transportation. The same policy should be applied to drones. Similarly, there are risks associated with the use of drones by law enforcement, but we should not let such concerns outweigh the enormous benefits that a drone-friendly economy can bring.

**7. Take ownership of Colorado's airspace.** There is no compelling reason why Colorado citizens should cede authority over the first few hundred feet of airspace to the Federal Aviation Administration, an agency that claims the authority solely through historical accident. Colorado should lead the way in creating a drone-friendly economy by dictating its own rules for where drones can fly and how.

Technology has always run ahead of the law; drones are no exception. But if we embrace drones with a clear understanding of the technology, the constituencies, and the social institutions necessary for human flourishing, we will have taken a significant step towards improving the quality of life for the people of Colorado.

## INTRODUCTION

Drones, the evolving term for pilotless vehicles that move through the air, have the potential to transform our world. They have applications across the spectrum of human economic and civic life. Like all technologies, they run ahead of law and policy, and bring with them both risks and rewards. On the risk side:

- They make the surveillance of private citizens easier.
- They are an ideal terrorist weapon.
- They can fall out of the sky.
- They make people think of evil flying robots.
- They can stalk you from the air.

On the other hand:

- Drones can do dangerous jobs better and cheaper.
- They have humanitarian applications.
- They can save lives.
- The market for drones is estimated to grow into the billions.
- Other countries are ahead of the US in private sector drone use.

Colorado's diversity presents unique challenges to policymakers thinking about drones in our airspace. We have federal, state, and private lands. We have natural beauty, and natural disasters. We have mountains over 14,000 feet high, and plains at around 3,000 feet. We have urban metropolitan areas with more than 5,000 people per square mile, and rural counties with fewer than one. We have military bases, the U.S. Air Force Academy in particular, and we have a town that offered a bounty to anyone who would shoot down a drone. Clearly there will be no simple, one-size fits all approach.

But with challenges come opportunities. The potential market for drones is enormous, once the regulatory structure is in place. Colorado and other states have a unique opportunity to get ahead of the game if they start thinking about the issues now. This Issue Paper is an attempt to assist in that process.

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## WHAT IS A DRONE?

Although there are as yet no hard and fast rules distinguishing drones from model airplanes, the following differences exist:

- 1. Fuel capacity.** Model planes have shorter flight time than drones. Typically, they can stay aloft for no more than an hour. Drones can remain in the air for much longer.
- 2. Line of sight requirements.** A radio-controlled model plane requires a line of sight between its human operator and the aircraft. Drones do not. In fact, the human operator can be sitting at a computer hundreds or even thousands of miles away.
- 3. Potential for autonomy.** Drones can be controlled in the same fashion as model airplanes, but they do not have to be. They have potential for both pre-programmed flight, in which the operator loads in the flight plan and then launches the plane, as well as more autonomous behavior, in which the drone is simply given a more general objective. Takeoff and landing can be completely autonomous.
- 4. Sensor capability.** This factor is probably the most important, certainly the dominant one from a policy perspective. Model planes are flown for the pleasure their owners get from flying them. The added value of drones comes from the data they gather and the tasks they perform. Drones are augmented with some sort of sensory data-gathering capability, such as cameras.
- 5. Interconnection and data integration.** Drones can transmit data to a ground station for future analysis and retrieval. Unlike model airplanes, drones also can communicate with other drones, with handheld devices, with the Internet, indeed with any wireless enabled device.

## WEAPONIZED DRONES

Readers familiar with the origin of the term “drone” will find the phrase “weaponized drone” an oxymoron, since the drone bees in the hive have no stingers. Weaponized drones are currently

the exclusive province of the military. Currently all such devices require a human operator to fire the weapon.

Firearms in the hands of the right people enhance public safety, while firearms in the hands of the wrong people threaten it. As of this writing, a weaponized drone adds no value in terms of deterrence or self-defense against violent criminals that is not currently provided by a firearm. In fact, there are numerous compelling reasons why such devices should remain only in the military sphere. Therefore, for the purposes of this Paper, the term “drone” refers only to unmanned and unarmed aircraft.

## HISTORICAL AND REGULATORY BACKGROUND

Drones were originally the exclusive province of the military. Unmanned radio-controlled aircraft date back to World War I. The use of unmanned balloons in war goes back further, to the 19<sup>th</sup> century. The military remained the only user of drones until roughly the dawn of the 21<sup>st</sup> century. Since that time, technological and economic forces have converged to make unmanned aircraft affordable to the general public. While large-scale fixed-wing drones like the AAI Aerosonde still cost several hundred thousand dollars, that figure is well within reach of private companies given the potential markets for what they can do. Mid-range units like the Zephyr are only a few thousand dollars per unit, and entry-level models like the AR Drone 2.0 are only a few hundred dollars. Prices are expected to come down while functionality goes up, as the market for these products becomes more mature. Provided, of course, the market for drones is permitted to function.

In February 2012, President Obama signed the FAA Air Transportation Modernization and Safety Improvement Act. Among other things, the Act mandated the incorporation of drones into the national airspace by September 2015. Although no

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one is sure if that deadline will be met, it is clear that progress is being made, and that one way or another drones are coming.

As a result of the Act, the FAA is authorizing six drone test sites, and has launched a competition among the states for proposals. (Colorado's proposal comes from CU's Research and Engineering Center for Unmanned Vehicles). The winners are expected to be announced in December. Also in response to the Act, the FAA now has a process in place for permitting drones to fly. Government agencies can request a Certificate of Authorization (COA) which, if approved, permits them to fly unmanned aircraft under the terms spelled out in the COA application.

However, this process is available only to public agencies flying unmanned aircraft. Private actors seeking to operate in the commercial realm are subjected to a much more onerous process.

They need a Special Airworthiness Certificate - Experimental Category (SAC-EC), which is extremely difficult to obtain and issued only for very narrow research purposes. This requirement is a tremendous barrier to entry for the private sector, one that must be removed if drone-based businesses are to become a reality.

The FAA's actions ought to be understood in the historical context of its mission: Safety first. The FAA is not in the business of creating wealth, promoting economic growth, or evaluating privacy concerns. The FAA's job is the creation of a safe airspace.

The problem with this approach is that the only way to achieve a completely safe airspace is to ground all aircraft entirely. Nor is it obvious

that the means pursued to safety by the FAA are the most cost-effective possible. Safety, like any other policy goal, involves costs and benefits, tradeoffs among various levels of risk. Achieving these tradeoffs through a centralized regulatory agency is

one way society can accomplish them, but it is by no means the only way, or even necessarily the best one. Markets, private institutions, and the common law also have ways of assigning and managing risk.

The costs of accidents in the air are often tragic and visible, but they must be balanced against the less visible social losses due to regulatory overreach, artificial barriers to entry, or the alternatives to regulation that were never permitted to emerge, a topic explored further in the pages that follow.

We should also point out that other countries, with less hostile regulatory regimes, are already using drones in private businesses. Japan and Canada, for example, are using drones for crop dusting, and have done so for years. The Association for Unmanned Vehicle Systems International estimates the potential economic benefit of drones to the U.S. economy to exceed \$80 billion during the next decade. The fact that those benefits cannot be realized until the regulatory climate is improved ought to be taken into account at all levels of policy making.

## WHO ARE THE STAKEHOLDERS?

Regulation and drone policy will affect a number of constituent groups. It is important to recognize that while their interests may sometimes conflict in theory, they do not have to in practice. Legislators should not assume that helping one group requires harming another, or that giving something to one necessarily requires another group to sacrifice.

Stakeholders in drone policy include the following:

- 1. Private citizens and advocacy groups concerned about privacy and civil liberties issues.** Ordinary citizens' primary exposure to drones has come through military and governmental use. Drone-based businesses are not yet here, and the benign uses of drones by public agencies are not likely to be encountered by most people in the course of their daily lives. Thus, the benefits drones offer are unfamiliar to most Colorado residents. Drones offer

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the potential for massive and unauthorized surveillance, and present a hitherto unknown threat to privacy. Therefore, private citizens have legitimate concerns about taking further steps toward a surveillance society in which they are being watched even though they have done nothing wrong. Advocacy groups like the ACLU have the legal expertise to advise on these issues, and in fact have already devoted considerable time and effort to drones. Their 2011 report "Protecting Privacy From Aerial Surveillance: Recommendations for Government Use of Drone Aircraft" should be read by anyone interested in this issue.

The challenge for Colorado regulators is to address these concerns while aggressively countering ill-considered attempts to ban drones entirely, since drones can provide enormous economic and social benefits.

## **2. Entrepreneurs seeking to use drones to start new businesses.**

These individuals stand to gain the most financially from the use of drones in Colorado airspace, since their activities cannot begin until the regulatory framework is sorted out. The potential for financial gain on their part should

not make them suspect. On the contrary, Colorado should welcome entrepreneurs and wealth creators with the skill and the expertise to use drones in a profit-making business. Their interest lies primarily in the creation of a stable, predictable regulatory regime with minimal bureaucratic obstacles and no artificial barriers to entry.

The objective for meeting the needs of this group is to create the kind of clear, simple and neutral regulatory regime that businesses require, while avoiding subsidies from the public treasury and the creation of special rules that privilege one company or groups of companies over others.

## **3. Law enforcement seeking more cost-effective ways of surveillance.**

Law

enforcement agencies can use drones in numerous ways. Borders can be patrolled more effectively and at lower cost. Arson and other criminal activities on open public land might be more easily detected. Drones at public events can provide better guarantees of public safety against threats, and in fact may be essential for countermeasures against drone-based attacks (see below). The challenge here will be to ensure that drones are used in ways that are strictly intended to help law enforcement carry out its existing roles, and not towards general surveillance in which agencies simply watch everything and wait for something to happen. The best available evidence so far shows that the blanket use of street surveillance cameras alone is neither a deterrent to crime nor particularly cost-effective. The same cost-benefit analysis ought to be applied to drone surveillance as well.

## **4. Government agencies seeking more cost-effective ways of carrying out their mission.**

Search and rescue operations, management of public land, flood control, forest fire fighting, virtually any government agency that requires the ability to search over large areas and make timely, data-based decisions can benefit from the use of drones. The challenge will be to encourage their use where it is cost-effective, while at the same time avoiding the temptation to purchase drones and use them simply for their novelty value, or for an agency to show how "cutting-edge" it is, or to use drones as a justification for larger budgets. Agencies who wish to use drones should be required to show how drone use saves money and/or reduces risk while enabling the agency to do its job better.

## **5. Private citizens who want to fly drones for fun.**

Although it might be tempting to minimize or even ignore the interests of model airplane and drone hobbyists, regulators

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should avoid doing so. The pursuit of private happiness is specifically mentioned in one of America's founding documents for a reason, and should not be stifled through regulatory zeal. Furthermore, model airplane hobbyists were among the first to investigate the use of drones for non-military purposes, and provided useful guidelines for their use long before the FAA became involved. Model airplane and recreational drone enthusiasts will support a growing industry, and will provide many useful insights that more highly credentialed "experts" might miss. Police and military users of firearms have benefited tremendously from the efforts of private citizens and hobbyists. Private citizens may find novel ways to improve drones which might never occur to risk-averse government agencies.

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**6. Non-profit, private organizations wishing to use drones.** Although it may not be obvious at first glance, numerous potential uses of drones exist in the non-profit sector. Human rights organizations have proposed using drones to monitor the activities of repressive regimes. At least two universities even have active Centers for Drone Journalism. Both currently are denied permission to fly outdoors by the FAA.

In addition to the usual regulations that govern non-profits, activities by non-profits to use drones should be subject to the same rules and regulations that affect all other private actors. For example, surveillance and monitoring of private citizens should be prohibited, property rights should be respected (both of and by the organization in question), and all organizations should be held accountable for their actions in their use of drones.

**7. The Federal Aviation Administration.** The FAA is, of course, the largest regulatory player by far in the area of drone use. The agency will expect all the states to follow its lead, and all proposed rules and regulations to be subject to its final authority. The FAA's interest is in safety above all, and like any government agency can be expected to fight hard to oppose any attempt to reduce the scope of its influence. Also, like any government agency, the FAA embraces change slowly if at all. The fact that it required an act of Congress to force them to integrate drones into the national airspace is telling.

In fact, in a classic example of technology running ahead of the law, the very question of the FAA's legal jurisdiction to regulate drones is under scrutiny. Raphael Pirker used a drone to take overhead images of the University of Virginia, and was fined \$10,000 by the FAA under regulations governing the conduct of commercial airline pilots. Pirker challenged the FAA, arguing that its operating rules do not permit the regulation of model aircraft. The case of *FAA vs. Pirker* is currently under appeal in an administrative law court.

However, if as expected, tens or hundreds of thousands of drones eventually fill the skies, effective management by a single national agency may very well become impossible *de facto*. Better solutions might include requiring some form of sense and avoid system (more on this in the supporting technology section of this paper), a concept that the FAA and others have endorsed. The FAA also has more institutional knowledge of airspace control and aircraft flow than any other group in the world. It can serve as a useful resource for ideas and a clearinghouse for information. But FAA regulations are not laws of physics, and Colorado ought not to accept them blindly.

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## WHAT ARE THE CHARACTERISTICS OF GOOD REGULATION?

Before discussing the specifics of drone regulation, it will help to review some basic principles of good regulation. What exactly typifies good regulation and public policy?

- 1. It makes use of existing law and policy when possible.** Good regulation does not duplicate existing efforts. It relies on what has gone before it when it can, and when it cannot it attempts to extend what has gone before by relying on precedent. This avoids wasted effort, reduces the burden of regulatory compliance, and reduces the risk of contradictory policy.
- 2. It is reviewed periodically.** Technology is frequently faster than the law. It changes faster and more often than the law can, because it is a very different process that serves a very different function. Thus good regulations that emerge in response to technology must be reviewed periodically. Questions that need to be asked include:
  - “Where is the technology now, as compared to when the law was written?”
  - “Are there any concerns we had back then that are no longer valid?”
  - “Are there any new concerns that should be addressed?”
  - “What do stakeholders and constituents think now, as opposed to when the law was written?”
- 3. It is based on explicitly stated principles.** What is the regulation for? What is it intended to do? What it is intended to avoid? What are the general principles on which it is based? What are the specific goals? Explicit statements of principle and specific intent can help clarify the regulatory regime, ease the anxiety of stakeholders, and help judges assigned with interpreting the system.
- 4. It does not treat people as means to an end, and takes the rights of individual citizens seriously.** America was founded on the idea of individual liberty, based on the Enlightenment philosophy that human beings were not means to an end but ends in themselves. Governments in turn are instituted to secure the basic rights of individuals. Any regulation or law that emerges from a legislative body should be drafted with individual rights foremost.
- 5. It promotes prosperity and punishes harm.** This requires an understanding of what benefits are to be expected from the technology in question, what the costs might be, and then providing a regime that encourages the former and punishes the latter. In particular, it provides an infrastructure of rules that permits those who promote prosperity to be rewarded (wealth creation) while at the same time punishing those who do harm (criminal violence, fraud).
- 6. It recognizes the problem of concentration in evaluating benefits and costs.** The task of the economist, as Frederic Bastiat said, is “to see what is not easily seen.” Because regulation is the product of a government body, it tends to respond to concentrations of costs and benefits—neglecting costs or benefits that are real but too diffuse to be politically visible. Good public policy recognizes the problem, and is explicitly designed to take diffuse costs and benefits into account.
- 7. It recognizes bottom-up solutions as well as top-down ones.** Under the right circumstances, the spontaneous interactions of private individuals in the marketplace are capable of producing solutions to the same problems that regulation is intended to solve. Such solutions, however, take time to emerge. Good policy allows for their existence, looks for them, and is careful not to crush them in the unbridled haste to regulate.
- 8. It is clear and predictable.** The basic rules under which a business or private citizen must operate ought to be understandable in plain language. Even more importantly,



notwithstanding the requirement for periodic review, regulatory regimes must be stable and predictable. People should be able to tell in advance whether or not an action they wish to pursue is illegal. Incredibly, this is not always the case.

**9. It is neutral, applying equally to all.** Good policy creates a level playing field. Not in the sense of guaranteeing equal outcomes, or even equal starting positions, but of the same rules applying to all. In particular, it avoids the use of regulatory power to give special privileges to some over others, even with the best of intentions.

**10. It internalizes externalities.** For those cases where individuals may be able to impose a cost on others while reaping the benefits for themselves, good policy will attempt to compensate for this as best it can. For those cases where a group of people benefit from a public good or service they do not themselves pay for, it will attempt to shift the costs to those who benefit the most directly, and will set aside funds received for that specific purpose.

### WHAT ARE THE REGULATORY ISSUES?

The principles discussed so far apply to regulation and public policy in general. What are the issues specific to drones? It might be helpful to begin with a comparison to familiar transportation technologies (see table 1).

Table I. How Drones Compare

Type of transport	Train	Car	Drone
Route	requires pre-existing tracks, approx. 233,000 miles in US	requires flat paved surface, approx. 8.5 million lane-miles in US	requires only air space
Type of movement	1-dimensional, starts and stops on track, difficult to remove from track, stops on track if fuel exhausted.	2-dimensional, starts and stops on road, relatively easy to remove from road, stops on road when fuel exhausted.	3-dimensional. When airborne, requires expenditure of energy. Fixed winged drones cannot stop or they will crash. Rotary wing drones must expend fuel even when stationary or they will crash. Both will crash once fuel expended.
Capacity	thousands of tons	1-10 tons (payload, towing)	a few ounces to hundreds of pounds
Passengers?	yes	yes	no
Private ownership	limited to corporate entities	private citizens	private citizens
Person required to steer?	not always (e.g. airport monorails)	legally yes, but driverless cars are already here and could be on the road within five years; primary barriers are regulatory/policy, not technological or economic.	no, not even remote control
Potentially autonomous?	yes (see above)	yes (see above)	yes
Regulatory regime	Federal Railroad Administration for freight and passenger trains	National Transportation Safety Administration (NTSA) for federal safety standards, also state motor vehicle agencies	FAA, but in flux
Cost to purchase	\$1,000,000's	\$1,000's	\$100's to \$100,000's
Value added	shipping large quantities of freight; secondarily, passenger transport	passenger and freight transport	warfare, data acquisition, photography, surveillance, agriculture, film, delivery/logistics, many others
Fatalities in peacetime civilian use	Hundreds	thousands	none reported, although peacetime civilian use currently severely restricted

The key differences are in ownership cost, value added, paths used, and nature of movement.

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## REGULATORY ISSUES – CONCENTRATION VERSUS DIFFUSE DRONE COSTS AND BENEFITS

As with any policy issue, the role of concentration in determining costs and benefits is extremely important with drones. In the present environment, the risk for paying more attention to concentrated factors than diffuse ones is particularly high. At the moment, the costs of drones are primarily more concentrated than their benefits, more easily imagined. Drone accidents, crashes, property

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damage, and possible fatalities will make compelling reading in the media, and make it easy to present worst-case nightmare scenarios. The specter of a surveillance society is a concentrated cost that is also very easily envisioned. These and similar hazards will easily enter the public consciousness as the integration of drones into public is contemplated. They should absolutely be considered in the regulatory process.

But it is equally important to envision the benefits that may not be so obvious: What new ideas will drone businesses propose? What new jobs will come into being? How much wealth will be created? What services will improve people's lives

that have not yet been invented? These are exactly the kind of benefits that only a diffuse system for knowledge discovery like the marketplace can foster. Enormous pressure will come to ignore these and similar benefits, as well as the temptation to impose diffuse costs. When it comes to costs and benefits of drones, legislators should endeavor to pay attention not only to what is easily imagined and to the effects on politically concentrated interests, but also to what economics tells us is real but not so easily imagined and to the effects on the politically unorganized.

## REGULATORY ISSUES – PUBLIC PERCEPTION OF AUTONOMOUS TECHNOLOGIES

An issue relating to human nature also comes into

play when drone-related questions are considered, one that arises only when autonomous, robot-like technology is involved. Human beings have highly evolved neural circuitry for distinguishing animate objects from inanimate, people from animals, and conscious beings from unconscious beings. That ancient ability, however, is not fully adapted for the modern world.

In particular, the human brain is wired to interpret things like independent movement, speech, and purpose as signs of life, consciousness, and even humanity. Robots, whether Sony's Aibo dog, an autonomous car, or a programmed drone, possess none of these attributes, but our brains misfire and generate a subconscious sensation that they do. Understanding this phenomenon can go a long way in anticipating public reaction to drones. For example, imagine the reaction to a manned police helicopter circling a stadium during a football game, versus an autonomous drone. Think of the Terminator movies and the evil Skynet robot. These are stories crafted by professional writers who understand what kind of entertainment is most likely to be compelling.

Thus we should expect some very visceral reactions to the idea of drones in our everyday lives, particularly as the technology permits them to develop increasing degrees of autonomy.

## REGULATORY ISSUES – PROPERTY RIGHTS

Property rights must play a fundamental role in drone regulation. Lawful drone owners have a property right in their drones, and deserve to be compensated if their drones are damaged or destroyed through the tortious acts of others. On the flip side, drones can damage others' property, for which those harmed should be able to collect damages from the owners of the drones responsible.

Much more problematic, but still important, is the notion of property rights to the air above one's

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home, what are known as air rights. The original doctrine of air ownership, before the invention of powered flight, was *Cuius est solum, eius est usque ad coelum*: "He who owns the soil, owns up to the sky."

In fact, there are good reasons not to recognize a property right that high. More modern interpretations now recognize the air thousands of feet above one's property to be essentially a public thoroughfare, owned by no one and subject to governmental regulation. This change is hardly surprising. Enforcing a strict notion of *Cuius est solum* and requiring consent for airlines to fly miles

above all private property would effectively make air travel impossible. And unlike land, borders delineating small quantities of airspace extended up in three dimensions are not easily established or enforced, an important prerequisite of property rights.

That being said, with the advent of drones, there may be good reasons to establish property rights to the air for some distance above private property.

Owners may not want to have drones flying so close to their homes. Consent seems clearly warranted before a drone can land on the roof of your house, so why shouldn't consent be required for a drone to hover a foot above it? Drones can still navigate over public roads, and can fly to people's homes who want them while avoiding residents who

want nothing to do with them. Remember too that property rights can be transferred. Skittish homeowners might be persuaded to sell, trade or rent their air rights to drone owners if the transaction leaves both parties better off than before.

The proper distance for air rights in a drone-friendly world is difficult to determine, but it is better to be approximately right than precisely wrong. In any case, it seems clear the question of air rights over private property will need to be re-examined in an era where drones are commonplace.

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## **WHAT IS THE SUPPORTING TECHNOLOGY LIKE, AND WHERE IS IT GOING?**

While the pace and direction of technology influences drones in many ways, three technological trends of fundamental importance stand out.

Cameras, whether drone-borne or not, are going to take pictures with better resolution, higher quality, and lower prices. Drone-imaging technology is only going to get better, with the distance from which a drone can recognize details like faces and license plates getting higher and higher every year. This trend poses tremendous risks for surveillance abuse, but also has great potential benefits for land management, weather forecasting, imaging, agriculture, and cartography, to name a few.

Artificial intelligence research in autonomous systems will make all forms of transportation less dependent on human guidance. For cars, this means removing the driver completely, including the use of remote controls. Such technology is already here, and is already spilling over into drone design. Drone movement, as we have seen, is distinguished from car movement, both in terms of the number of dimensions and in the environment it must operate in. In some sense, autonomous drone operations is an easier problem to solve than autonomous cars, since apart from other aircraft, the environment does not require interaction with people.

That being said, controlling interaction with other aircraft remains a challenge. Drones will increasingly crowd the skies and, in the absence of a pilot, need some way to avoid one another. The likely solution will be some form of *Sense and Avoid System*, or SAS. Drones can be programmed with software and transmission devices to inform all others within a specific range of their speed and position, implementing a protocol that takes over if drones are too close to one another. These types of systems are currently in the experimental stages. However, based on the success of autonomous cars,

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a much more challenging problem, it seems likely that these systems will mature quickly and be ready for deployment in the near future.

## BASIC PRINCIPLES OF DRONE REGULATION

An examination of specific guidelines for drone regulation requires careful consideration of public and private actors, and the benefits and risks of each. While an imperfect classification, it will foster better management of the complexity of drone regulation.

Table 2. Benefits and Risks of Drone Use

	Benefits	Risks
Private actors	drone-based businesses (estimated dollar value in billions over the next several years) drone journalism, humanitarian causes, remote surveillance of one's private property, recreation	citizen-on-citizen spying, harassment, stalking, corporate espionage, theft of trade secrets and intellectual property, tortious acts, negligent use, criminal acts, unauthorized use/aggregation of personal information, rent-seeking
Public actors	search and rescue, traffic flow monitoring, public land management, more cost-effective ways to accomplish agency missions	increased momentum toward surveillance society, lack of privacy, further erosion of Fourth Amendment protections, use of drones solely to increase budget, scope, power of agency

### GOAL 1 – SUPPORTING THE BENEFITS OF DRONE USE BY PRIVATE ACTORS

The most important action policymakers can take to permit private citizens to realize the benefits of drones is to remove the regulatory barriers that prevent them from flying. This responsibility largely rests in the hands of the FAA, and might seemingly be beyond the control of any state legislature (but see the section on “Federalism” below).

Another important action here is negative: Drone entrepreneurs should be allowed to keep the wealth they create, and not be subject to any special taxes simply because the state government claims to need the money. By that same token, drone ventures should not be subsidized, even if other states show poor judgment in doing so. Drone businesses do not meet the economic definition of a public good (where equal access is both efficient and necessary), and therefore should not be subsidized. Special taxes on drone-based businesses, if any, should be resisted

until the industry is sufficiently mature to determine exactly what externalities they impose and how they can best be internalized.

### GOAL 2 – MITIGATING THE RISKS OF DRONE USE BY PRIVATE ACTORS

Wherever possible, the law of torts and criminal law should be extended to cover property damage and criminal acts in which drones are involved. Existing codes and statutes should be reviewed to confirm that drones cannot be used in harmful ways that somehow could not be prosecuted under Colorado law. After appropriate review, the legislature could rectify problems through appropriately drafted modifications to the law.

As necessary, expanding current law and precedent will be the best approach to deal with private spying, stalking, theft of intellectual property, corporate espionage, and similar affronts.

Some private actors will engage in rent-seeking behavior, attempting to extract funds or special privileges from the public for their particular venture or cause. Such activities are often cloaked in noble-sounding rhetoric, but ultimately come down to self-seeking behavior applied to the political process. Legislators often are sympathetic to these kinds of activities when the actors in question come from their district, or represent a large bloc of voters. Nonetheless, subsidies and privileges of any form should be resisted. The best way, the most ethical and fair way, for businesses to grow is to sink or swim based on their own merits. Entrepreneurs, customers, and private citizens acting in the market are the ones best qualified to pick winners and losers in this newly emerging field, free of the distortions of subsidy and privilege.

Limited liability should be avoided, as it creates a moral hazard and reduces the incentive for drones to operate safely. Whatever the reasons for limiting liability might be in areas where the results of an accident or a natural disaster could be catastrophic, they do not apply to drones.

*Wherever possible, the law of torts and criminal law should be extended to cover property damage and criminal acts in which drones are involved.*

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### GOAL 3 – SUPPORTING THE BENEFITS OF DRONE USE BY PUBLIC ACTORS

Every state agency that believes it could make effective use of drones to accomplish its mission

*Every state agency that believes it could make effective use of drones to accomplish its mission should submit proposals to do so. Likely tasks include, but are hardly limited to, search and rescue operations, state land management, tourism promotion, and transportation analysis.*

should submit proposals to do so. Likely tasks include, but are hardly limited to, search and rescue operations, state land management, tourism promotion, and transportation analysis.

But the soundness of any such proposal should be rooted entirely in cost-effectiveness and the ability of agencies to do their stated jobs more effectively. Because drones are the “next big thing,” tremendous incentives will emerge for agencies to include drones in their budgets simply because they are high-visibility, big ticket items. Higher-end drone models are not cheap, and can easily be used to justify budget increases in a time

of fiscal austerity. Drones in the public realm are not a magic bullet. They only should be used when agencies can show clear cost savings and benefits to the public.

### GOAL 4 -- MITIGATING THE RISKS OF DRONE USE BY PUBLIC ACTORS

This area is likely to generate the most public concern, and therefore requires the most careful attention. The ACLU is correct that warrants should be required for all uses of drones in search and surveillance missions by law enforcement. Similar to existing requirements for issuing warrants, drone-based warrants should be narrowly focused, restricted to specific persons, goods and/or places to be imaged. *This is particularly important when drones are involved, because their range is broader than any surveillance device that has come before it.* All Colorado judges in a position to issue warrants should be made aware of this issue, perhaps through Continuing Legal Education courses or a similar professional venue.

Fortunately, the same technology that makes drones unprecedented risks towards a society of perpetual surveillance also makes them easier to operate

in a transparent and open way. It is possible, for example, to record all the flight paths of public sector drones with time-stamped GPA coordinates, to download them to a central location, and to put them online in a publicly available database. Such a database would be a tempting target for hackers, and ultimately could not be made immune from alteration and tampering by insiders. Good computer security practices and appropriate criminal penalties could help maintain public confidence that drones are being used in ways consistent with the public’s desire to deter criminals without the perpetual monitoring of law-abiding citizens who have done nothing wrong.

In fact, similar to the advantages of community-based policing, community-based policies toward drones may be the most effective in terms of public acceptance. Rather than a one-size-fits-all approach, it would be wise to allow for community input on what kind of drone use citizens want in their law enforcement, or even if they want to permit drones for law enforcement at all. Different communities will have different policing needs, and may prefer different tradeoffs on the freedom/security spectrum. They may even change their minds over time.

That being said, Colorado should avoid the temptation to ban drones entirely, a temptation more likely to spring from this area than any other. As disturbing as the image of a drone-based surveillance society is, we would do well to remember that any technology can be used for good or ill.

We should be careful not to throw out the baby of a wealthier world with the bathwater of a less private one.

### CROSS-BOUNDARY REGULATORY PRINCIPLES

Some principles of regulation cross the boundaries of the table above, in that they can accomplish more than one of the four goals simultaneously. Some of the following have been touched on already.

*We should be careful not to throw out the baby of a wealthier world with the bathwater of a less private one.*

**Property rights** – Protecting property rights of drone owners as well as property rights of people harmed by drones through accidents, negligent, or tortious acts both can promote the benefits of drone use and mitigate their risks. Ideally, this goal could be accomplished not through new legislation but through the application of common law of property and torts to the use of drones.

**Individual consent** – Wherever possible, the principle of individual consent should be used to distinguish between beneficial and harmful uses of drones. For example, when a drone lands on a person’s porch, the question of whether or not that is criminal trespass or a mutually beneficial exchange (it might be bringing pizza) can be resolved with the issue of consent. How might we determine whether a drone-based video of a child’s birthday party is a cherished family memory or unauthorized surveillance? Again, the question of consent can help determine the answer.

**Individual responsibility and accountability** – Good regulation permits individual citizens to reap the rewards of their efforts, but at the same time holds them

responsible and accountable. Drones offer potential challenges in this area because, unlike model planes, they do not require a human in close proximity. Every drone ought to be traceable to some individual or entity who is ultimately responsible for its actions. This recommendation is particularly important for autonomous drones, to avoid the

dangerous impression that a self-directed device is somehow responsible for its actions, as opposed to its programmers or the owners who put it into the air.

It seems likely that some private businesses would enthusiastically place their logo on any drones they use, as would public agencies. Voluntary solutions like self-registration in a user community’s database may also emerge. All drones need to be easily associated with the individuals or agencies

responsible for them. At least as of this writing, little potential benefit and enormous potential for harm can be seen in the use of anonymous drones used by public or private actors alike.

## THE ROLE OF INSURANCE

As one prominent speaker at a recent drone conference remarked, “Insurance is the 800-pound gorilla in the room.” Without mechanisms to spread risk, to assign liability, and ensure the minimum standards of risk reduction required to operate a business, the drone-based economy will never get off the ground.

Of course, the same could have been said for the automobile-based economy 100 years ago. So once again, caution and patience are warranted here. How to evaluate risk, whether or not to self-insure, how much capitalization is required for responsible underwriting, are all extremely complex, distributed decisions that markets are best equipped to handle. Given the powerful incentives in place for buyers and sellers of insurance to come to terms in the drone market, regulators should give bottom-up solutions time to emerge before imposing top-down solutions. Regulators also should remember that perfection is not an option. Regulating the insurance market through mandatory purchase requirements, limited liability, and other preemptive policy initiatives also have costs that may or may not justify the benefits.

The Colorado Division of Insurance surely will have a role to play here, and at the very least should begin thinking about this issue. But they should not move too quickly, and should give voluntary, market-based solutions a chance to emerge.

## THE ROLE OF FEDERALISM

Drones are an example of technology moving ahead of the law. The Federal Aviation Administration was created long before private drone use was even imaginable. Its present role in the regulation of drone use is a historical accident, arrived at simply

*Without mechanisms to spread risk, to assign liability, and ensure the minimum standards of risk reduction required to operate a business, the drone-based economy will never get off the ground.*

*Every drone ought to be traceable to some individual or entity who is ultimately responsible for its actions.*

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because it was the only agency available to fill the regulatory vacuum.

We would argue, however, that the mission of the FAA as it is presently constituted makes it a poor caretaker of drone airspace. The FAA was created in response to the first major air disaster involving loss of life. Accordingly, its self-described mission is "Safety first." Such a mission is possibly appropriate to the administration of cross-country airspace with planes that carry passengers. But such an approach

***Even if it makes sense for the FAA to regulate airspace around airports and thousands of feet above the ground where city-to-city flights take place with live passengers, there is no compelling reason why society should grant the agency the same authority for passenger-less drone flights a few hundred feet off the ground.***

has drawn the ire of drone users everywhere. They face enormous regulatory barriers to flying their craft and getting their businesses off the ground, barriers designed in an era when planes needed pilots and carried passengers. Instead of "Safety first," the FAA's mission might be better translated as "Safety *Über Alles*."

Even if it makes sense for the FAA to regulate airspace around airports and thousands of feet above the ground where city-to-city flights take place with live passengers, there is no compelling reason why society should grant the agency the same authority for passenger-less drone flights a few hundred feet off the ground. The concept of "national airspace" may have some sort of meaning at 30,000 feet, but it becomes increasingly less

tenable tens or hundreds of feet above a town. That airspace is better seen as appropriate to, at most, regulation by individual states, or perhaps even individual towns.

The present regulatory regime has real-world consequences. According to Tim Reuter, a drone entrepreneur interviewed by CNN:

*We're allowed to do whatever we want as recreational users, but as soon as you start charging money, you need to get a license from the FAA, and there's no way to get that license as a private citizen. So right now, America*

*is sitting on its hands, while around the world people are starting small companies that are going to turn into big companies that we're going to have to compete against.*

Prof. Randy Beard of BYU's Unmanned Aerial Systems research center notes that "[current FAA policies] make it completely impossible to include undergraduates in our research or to have undergraduate projects where experimentation and time in the air is essential. Current regulations definitely get in the way of quality educational experiences, especially for undergraduates."

A state airspace regulatory agency could choose to copy any rules the FAA proposes, but it would not have to do so. Different states might find different ways to balance drone costs and benefits, based on their own unique economic circumstances, enthusiasm for drone-based businesses, concerns about drone-based surveillance, and so forth. Bordering states have strong incentives to come to agreements regarding cross-boundary use of drones, but they also could compete with one another and a process of knowledge discovery to find the best ways to regulate drones in ways that enhance the quality of life for their citizens.

This form of competition is highly beneficial, and is one of the advantages of our federalist system of government. The time seems ripe for Colorado and other states to take control of the lowest regions of its non-airport and non-military airspace away from the FAA and assume responsibility for drone regulation themselves.

## **CONCLUSION**

The mandated integration of drones into the airspace by 2015 presents Colorado and other states with a unique opportunity. If policymakers are able to resist knee-jerk responses and instead focus on promoting the benefits of drone use while mitigating the risks, following the principles outlined here, they will take a significant step towards economic growth and a better life for the people of Colorado

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<p>"Sample COA Application" <a href="http://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/systemops/aaim/organizations/uas/media/COA%20Sample%20Application%20v%201-1.pdf">http://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/systemops/aaim/organizations/uas/media/COA%20Sample%20Application%20v%201-1.pdf</a></p>	<p>FAA UAS Test Site Map, <a href="http://www.faa.gov/about/initiatives/uas/media/UAS_testsite_map.pdf">http://www.faa.gov/about/initiatives/uas/media/UAS_testsite_map.pdf</a></p>

Drone-based businesses	
Aibotix (hand-launched unmanned helicopter) <a href="http://www.aibotix.com/about-aibotix.html">http://www.aibotix.com/about-aibotix.html</a>	Yamaha (pilot-optional helicopters) <a href="http://rmax.yamaha-motor.com.au/faq">http://rmax.yamaha-motor.com.au/faq</a>
FieldOfView (agricultural imaging) <a href="http://fieldofviewllc.com/about">http://fieldofviewllc.com/about</a>	UAV Solutions (UAV manufacturer) <a href="http://uav-solutions.com/">http://uav-solutions.com/</a>
DJI (high-performance UAS manufacturer) <a href="http://www.dji.com/company/">http://www.dji.com/company/</a>	Aerial Technology International (hi-res aerial imaging) <a href="http://www.aerialtechnology.com/">http://www.aerialtechnology.com/</a>
Scion UAS (pilot-optional helicopters) <a href="http://www.scionuas.com/">http://www.scionuas.com/</a>	Airware (UAS software developer, Google is a multimillion dollar investor) <a href="http://www.airware.com/">http://www.airware.com/</a>

Drone advocates, critics, research centers	
Association for Unmanned Vehicle Systems International home page, <a href="http://www.auvsi.org/Home/">http://www.auvsi.org/Home/</a>	Research and Engineering Center for Unmanned Vehicles, University of Colorado at Boulder, <a href="http://recuv.colorado.edu">http://recuv.colorado.edu</a>
Droneswatch: A coalition campaign to monitor and regulate drone use, <a href="http://droneswatch.org/">http://droneswatch.org/</a>	Center for Unmanned Aircraft Systems, Brigham Young University, <a href="http://c-uas.byu.edu/">http://c-uas.byu.edu/</a>
DIY Drones: The Leading Community for Personal UAVs, <a href="http://www.diydrones.com">www.diydrones.com</a>	Conservation Drones, <a href="http://conservationdrones.org">http://conservationdrones.org</a>

Other sources	
American Road and Transportation Builders Association FAQs: <a href="http://www.artba.org/faqs/#9">http://www.artba.org/faqs/#9</a>	National Census of Fatal Occupational Injuries in 2012 (Preliminary Results), Department of Labor Statistics, US Department of Labor, <a href="http://www.bls.gov/news.release/pdf/cfoi.pdf">http://www.bls.gov/news.release/pdf/cfoi.pdf</a>
National Highway and Traffic Safety Administration data tables: <a href="http://www.fars.nhtsa.dot.gov/Main/index.aspx">http://www.fars.nhtsa.dot.gov/Main/index.aspx</a>	"The Collaborative Colorado–Nebraska Unmanned Aircraft System Experiment," Bulletin of the American Meteorological Society, Jan 2012, <a href="http://journals.ametsoc.org/doi/pdf/10.1175/2011BAMS3073.1">http://journals.ametsoc.org/doi/pdf/10.1175/2011BAMS3073.1</a>
Train and track safety: Tracks and statistics. Minnesota Safety Council. <a href="http://www.minnesotasafetycouncil.org/facts/factsheet.cfm?qs=01FCA7EB457958B8F908D7D68B570E85">http://www.minnesotasafetycouncil.org/facts/factsheet.cfm?qs=01FCA7EB457958B8F908D7D68B570E85</a>	

In addition to previously cited sources, the author gratefully acknowledges the assistance of Jonathan Rotner and the DC Drone Users Group.

## APPENDIX: DRONE EXAMPLES



Amazon "octocopter" drone.



Projets Rq-11 Raven



Experimental UAS designed at the Research and Engineering Center for Unmanned Vehicles, University of Colorado at Boulder (<http://recuv.colorado.edu>)



SQ-4 handheld drone, SQ-4, developed at Middlesex University's Autonomous Systems Laboratory in London



The Aibotix Hexacopter (<http://www.aibotix.com/>)



Northrop Grumman RQ-4 Global Hawk (Wikipedia)



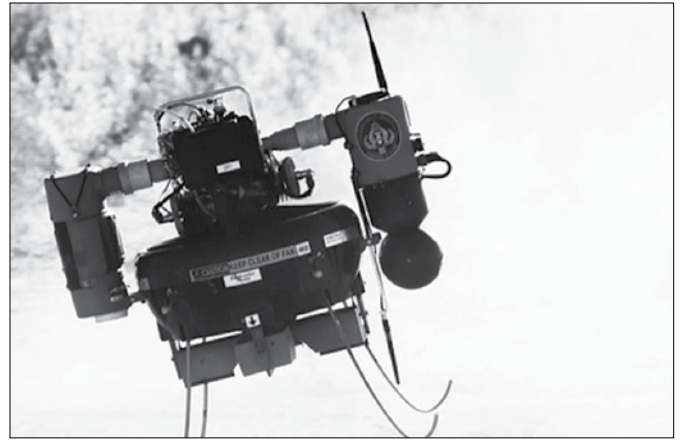
The Aibotix Yamaha RMAX robotic crop duster – “World’s most advanced non-military UAV” (<http://rmax.yamaha-motor.com.au/>) (<http://www.aibotix.com/>)



The TechPod, designed by entrepreneur Wayne Garris as a Kickstarter project, \$800 ready-to-fly at <http://hobbyuav.gostorego.com/>. Tested in Belize by conservationdrones.org.



Parrot AR Drone 2.0 (\$300 on amazon) (<http://ardrone2.parrot.com>)



The 18-pound Honeywell T-Hawk, used to inspect Japan’s Fukushima Power Plant when radiation levels were too high for humans. (<http://www.theatlantic.com/technology/archive/2011/04/inside-the-drone-missions-to-fukushima/237981/>)



Workers from the World Wildlife Fund use camera-equipped drones to protect Nepal’s endangered species from poachers (<http://www.bbc.co.uk/news/science-environment-18527119>)



Shadow Drone, Montgomery County Sheriff’s Office (\$300,000, one tenth the cost of a helicopter) (<http://www.motherjones.com/mojo/2012/12/drones-nonmilitary-farming-hurricanes-poachers>)

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