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# **Dronology: A System for Multi-UAV Flight Planning and Execution**

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# Drones: Mail Delivery



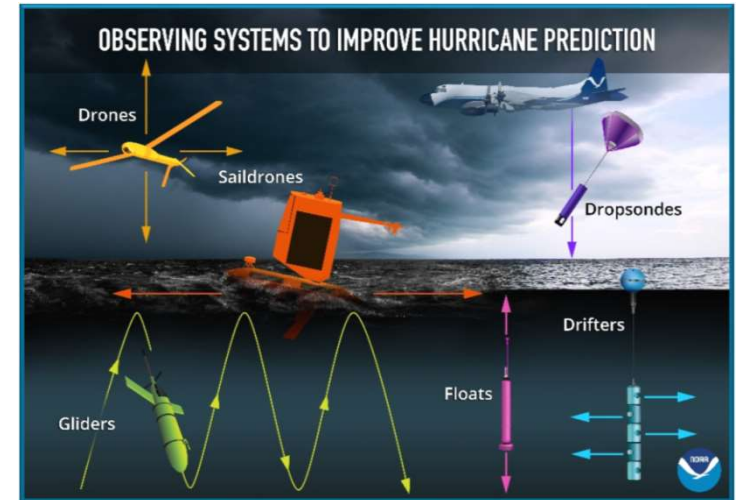
Canadian Royal Mail is considering using drones for autonomous mail delivery.

# Drones: Police Activity



Several police departments around the world are piloting the use of drones to search for missing people, monitor traffic accidents, and to explore crime scenes.

# Drones: Hurricane Observation



NASA and Northrop Grumman are working on a \$30-million experiment to use long-range Unmanned Aerial Vehicles (UAV) to spy on storms as they evolve.

# Drones: First Responder Support



Drones help firefighters see in the low light conditions, inspect buildings, check for hot spots in burning buildings, and search for missing persons.



# Drone Applications are Cyber-Physical Systems

In Cyber-Physical Systems, **physical** and **software components** are **deeply intertwined**, able to operate on different spatial and temporal scales.



# Drone Applications are Safety-Critical!

- **Prevent hazards from occurring such as:**
  - Landing or descending in an unsafe area such as on top of a person's head, in traffic etc.
  - Crashing into other drones during flight and causing debris to rain down.
  - Flying into the flight path of an airplane.
  - Flying in any other way which might cause an accident.





# Drones in the News...



**Totally uncool California bureaucrats shoot down drone weed delivery**

[https://www.theregister.co.uk/2017/09/11/california\\_kills\\_drone\\_weed\\_delivery](https://www.theregister.co.uk/2017/09/11/california_kills_drone_weed_delivery)

**Immer mehr Drohnen-Vorfälle an deutschen Flughäfen**

Flugzeugpiloten werden im deutschen Luftraum immer häufiger durch Drohnen behindert.

<http://diepresse.com/home/wirtschaft/economist/5288603/immer-mehr-DrohnenVorfaelle-an-deutschen-Flughaefen>

**The new flying squad: Radical police plan to use drones in hunt for suspects - and even deliver supplies to victims cut off by floods**

<http://www.dailymail.co.uk/news/article-4891496/Police-plan-use-drones-hunt-suspects.html>

**Poor software design led to second £1m Army spy drone crash**

Thales Watchkeeper WK006 dived itself into Boscombe Down's runway  
12/2016

**United Airlines flight forced to avoid drone flying near runway at Newark airport**

<http://www.foxnews.com/travel/2017/08/01/united-airlines-flight-forced-to-avoid-drone-flying-in-near-runway-at-newark-airport.html>

**OUT OF SIGHT —  
Drone collides with US Army helicopter, puts 1.5" dent in rotor**  
Collision at 300 feet reveals limits of "trusting the app."  
12/2017

# Drone Accidents



[http://www.brooklyndaily.com/stories/2014/50/bn-drone-disaster-at-tgifridays-2014-12-12-bk\\_2014\\_50.html](http://www.brooklyndaily.com/stories/2014/50/bn-drone-disaster-at-tgifridays-2014-12-12-bk_2014_50.html)

TGI Friday's created the "Mistletoe Drone" which flew around the restaurant carrying mistletoe – to encourage patrons to kiss.

Unfortunately, it went out of control and clipped off the tip of a photographer's nose!

# Drone Accidents



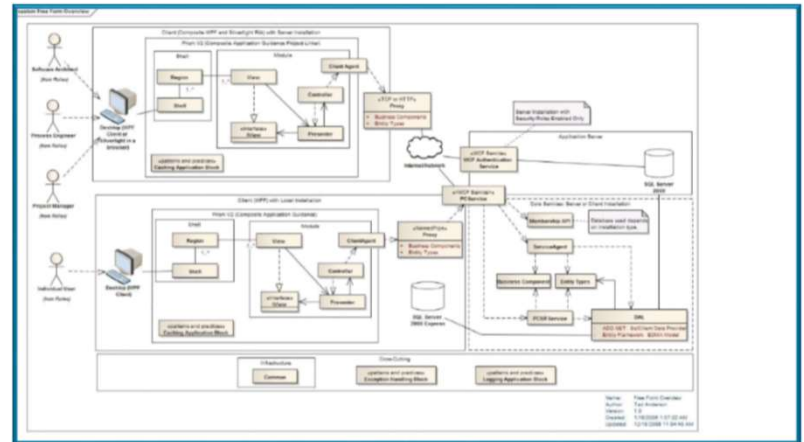
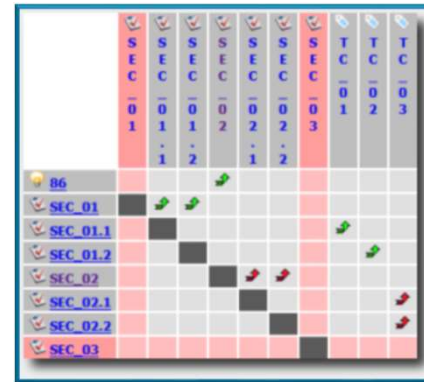
<https://www.youtube.com/watch?v=jvjfwSKYxV4>

Marcel Hirscher almost suffered a direct hit from a 22lbs (10kg) drone mid-race at Madonna di Campiglio. This is the reason broadcast drones are no longer allowed at ski races



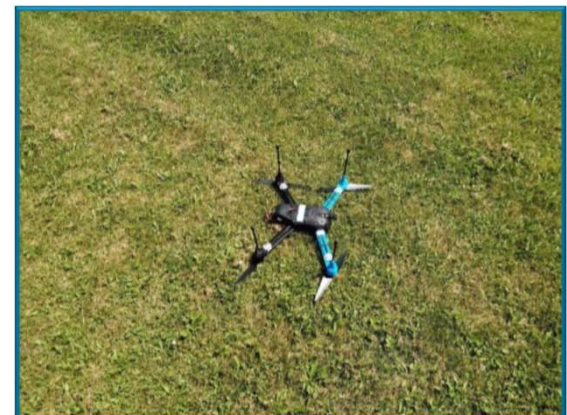
# Follow a Thorough Design and Engineering Process!

- Define clear system goals and Use Cases
- Specify Requirements
- Create Design
- Validate Architecture
- Establish Traceability
- Review Code Quality
- Perform Tests
- Document Safety Requirements
- ....



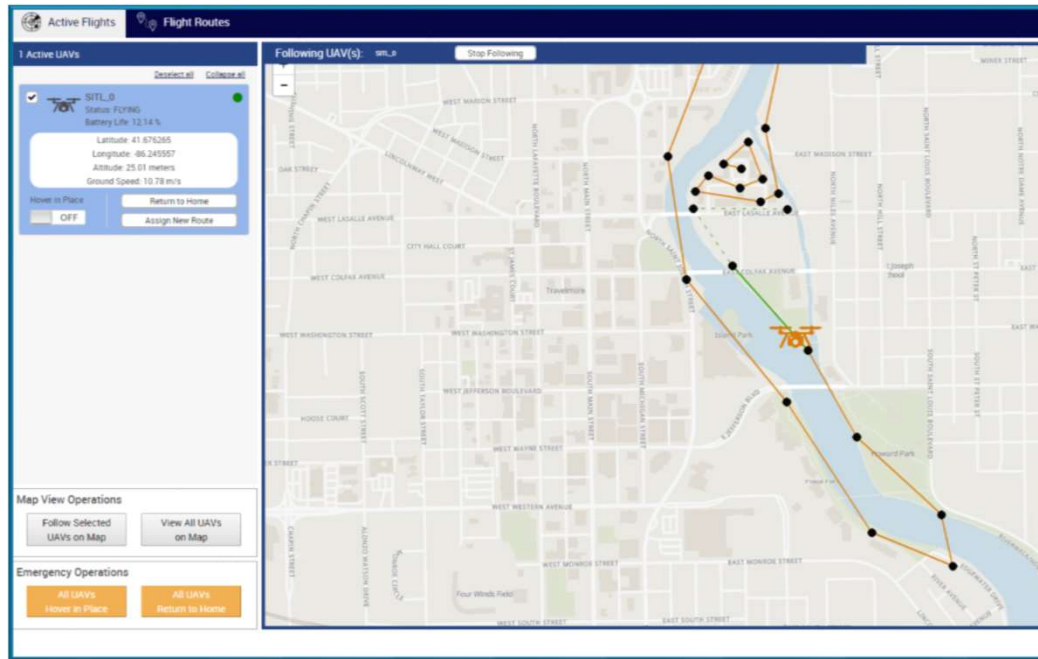


# Dronology





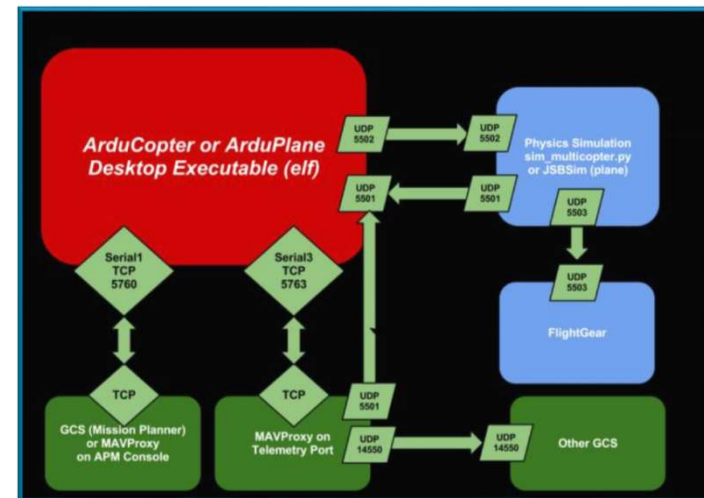
# Dronology System Requirements & Architecture



# Simulation vs. Real Drones

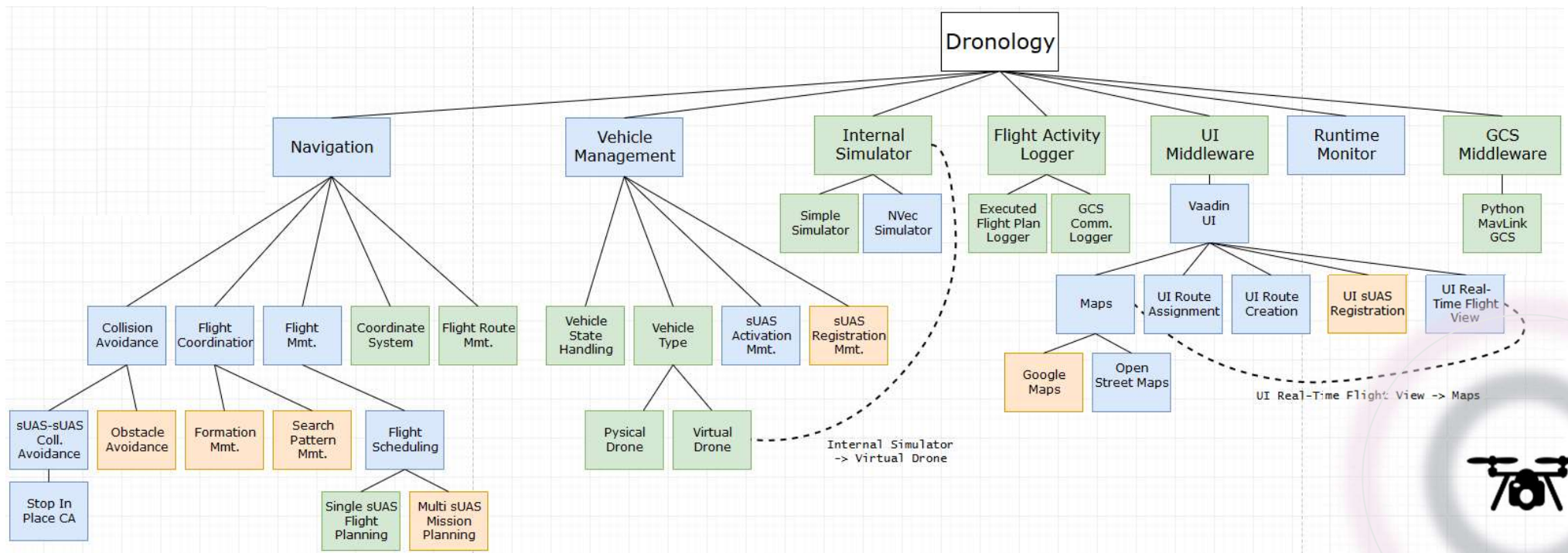


Real Hardware

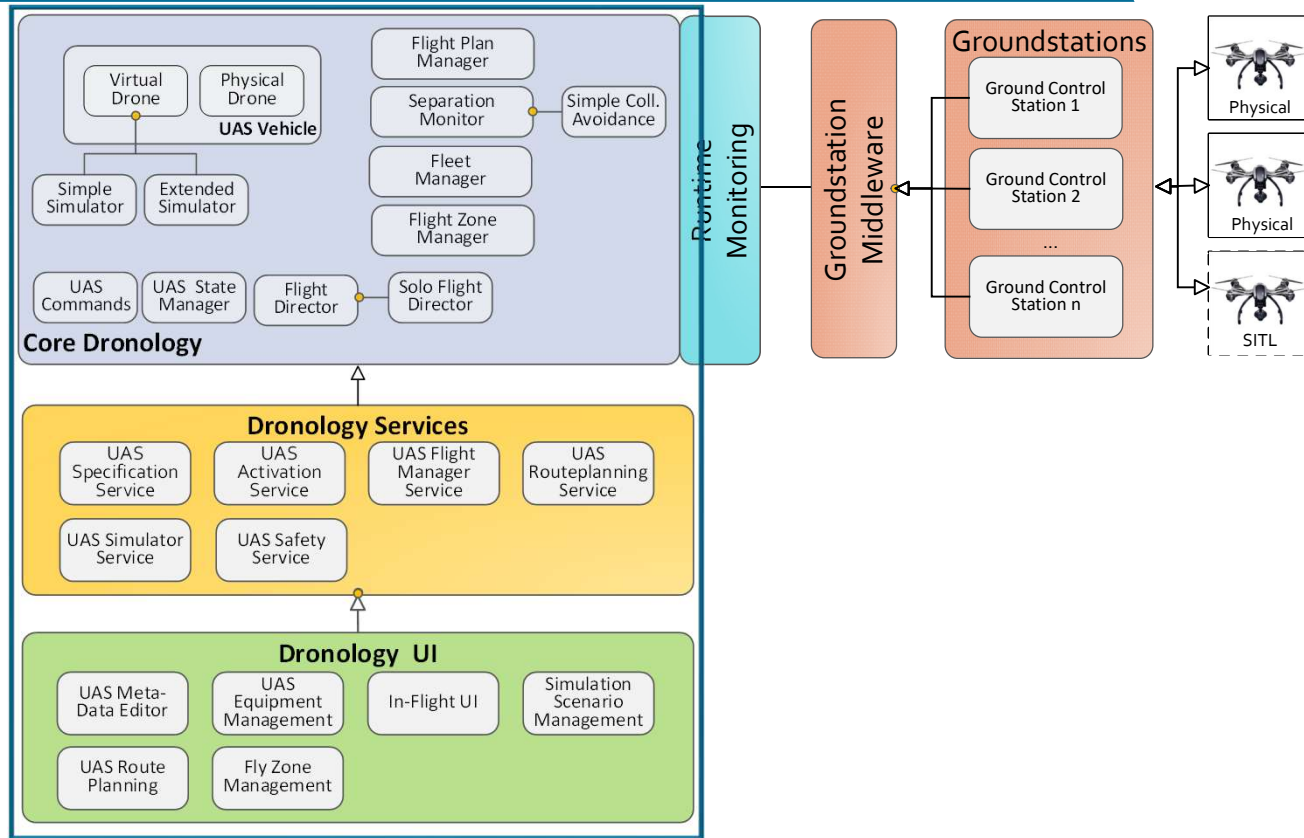


Software-in-the-loop (SITL)

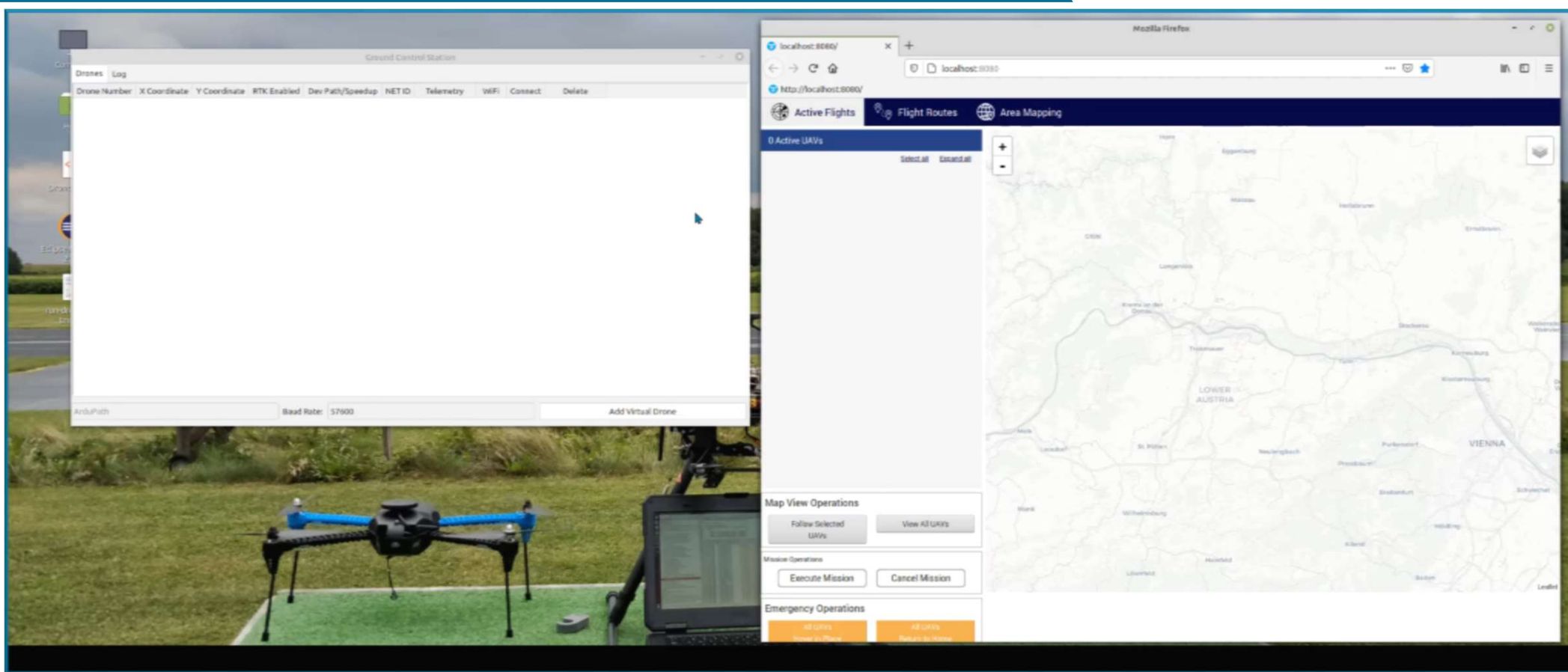
# Dronology Features



# Dronology Architecture



# Dronology Application & User Interface: Mockup





# Dronology Dataset: Requirements, Use Cases...

Dronology_Dataset					
File Edit View Insert Format Data Tools Extensions Help Last edit was made on September 6 by anonymous					
100% 123+ Open Sans 12					
Nr.					
A	B	C	D	E	F
Nr.	Type	ID	Name	Description	Related Elements
1	Cmp	CO-90	GCS Middleware	Handles connections between Dronology and Ground Control Stations (GCS). Forwards commands monitoring and other messages from Dronology to its registered GCS and passes messages describing the state of the UAVs managed by each GCS back to Dronology.	DD-354 - DD-361 - DD-710 - DD-711 - DD-712 - DD-713 - DD-715 - DD-716 - DD-718 - DD-719 - DD-720 - DD-721 - DD-723 - DD-724 - DD-727 - DD-728 - DD-730 - DD-731 - DD-732 - DD-733 - DD-734 - DD-735 - DD-737 - DD-763 - DD-768 - RE-160 - RE-709 - RE-714 - RE-722 - RE-729 - RE-736
2	Cmp	CO-91	GCS Middleware	Python based system that manages and controls UAVs. Communicates with Dronology via the Ground Station middleware. Each GCS is responsible for communicating directly with each UAV sending it commands and monitoring its state including its current position flight mode and health.	DD-740 - DD-742 - DD-743 - DD-744 - DD-745 - DD-747 - DD-748 - DD-749 - DD-750 - DD-752 - DD-753 - DD-755 - DD-756 - DD-757 - RE-235 - RE-739 - RE-741 - RE-746 - RE-751 - RE-754
3	Cmp	CO-105	UI Real-Time Flight View	Manages all aspects of displaying flights and UAVs in real-time and interacting with them. The flight view displays active routes UAV coordinates and their current health. The map uses zoom and panning features to follow one or more selected UAV.	DD-113 - DD-121 - DD-229 - DD-682 - DD-683 - DD-684 - DD-685 - DD-686 - DD-687 - DD-688 - DD-690 - DD-692 - DD-694 - DD-696 - DD-697 - DD-699 - RE-114 - RE-120 - RE-681 - RE-689 - RE-691 - RE-693 - RE-695 - RE-698
4	Cmp	CO-184	Internal Simulator	The internal simulator provides low-fidelity features for supporting quick initial tests of a virtual UAV. Features include takeoff goto land and battery health.	RE-593 - RE-594 - RE-595 - RE-596 - RE-597
5	Cmp	CO-472	Flight Route Manager	Provides capabilities for creating and managing flight routes within Dronology.	DD-502 - DD-504 - DD-506 - DD-507 - DD-509 - DD-75 - RE-501 - RE-503 - RE-505 - RE-508
6	Cmp	CO-473	Coordinate System	Provides 3 dimensional coordinate system currently based on longitude latitude and altitude. Provides conversion between various coordinate systems.	DD-177 - DD-23 - DD-24 - DD-511 - DD-512 - DD-513 - DD-514 - DD-515 - DD-518 - DD-519 - RE-510 - RE-516 - RE-517 - RE-77
7	Cmp	CO-474	Flight Manager	Provides basic flight related capabilities for UAVs.	DD-520 - DD-522 - DD-524 - DD-526 - RE-424 - RE-521 - RE-523 - RE-525
8	Cmp	CO-475	Flight Scheduling and Execution	Provides capabilities for executing flights assigned to a UAV.	DD-532 - DD-533 - DD-534 - DD-535 - RE-531
9	Cmp	CO-476	Mission Planning	Provides capabilities for executing missions with multiple UAVs	DD-362 - DD-468 - DD-498 - DD-536 - DD-537 - DD-538 - DD-540 - DD-542 - DD-543 - DD-544 - DD-546 - RE-541 - RE-545 - RE-759
10	Cmp	CO-477	Single UAV Flight Plan Scheduler	Single UAV flight plan assignments (taking an existing route instantiating it and assigning to a UAV)	DD-27 - DD-548 - DD-550 - DD-552 - DD-553 - DD-554 - DD-556 - DD-557 - DD-559 - DD-560 - DD-561 - DD-81 - DD-84 - DD-85 - DD-87 - RE-100 - RE-101 - RE-103 - RE-28 - RE-547 - RE-549 - RE-551 - RE-555 - RE-558 - RE-86
11	Cmp	CO-480	Flight Patterns	Provides capabilities for creating and executing complex flight patters for multiple UAVs	RE-562 - RE-563
12	Cmp	CO-481	Object Avoidance	Collision Avoidance API and general services	DD-564 - DD-565 - DD-566 - DD-567 - DD-568 - RE-124 - RE-125 - RE-126 - RE-127
13	Cmp	CO-484	Stop In Place	Simple collision avoidance implementation that stops UAVs when they violate a minimum safety distance.	DD-569
14	Cmp	CO-570	Vehicle Core	Core component for managing different types of UAVs.	DD-26 - DD-30 - DD-31 - DD-32 - DD-33 - DD-500 - DD-527 - DD-528 - DD-529 - DD-530 - DD-571 - DD-572 - DD-573 - DD-575 - DD-577 - DD-578 - DD-579 - DD-580 - RE-25 - RE-38 - RE-574 - RE-576 - RE-8 - RE-80
15	Cmp	CO-582	UAV Activation Manager	Provides capabilities for activating and deactivating both Virtual and Physical UAVs within Dronology.	DD-583 - RE-584 - DD-585 - DD-586 - DD-588 - DD-590 - RE-161 - RE-36 - RE-587 - RE-589
16	Cmp	CO-591	UAV Registration Manager	Provides capabilities for registering UAVs i.e. providing meta-data regarding the UAV (such as payload wingspan equipment...)	RE-592
17	Cmp	CO-598	Simple Simulator	Provides basic capabilities for simulating the flight of Virtual UAVs.	DD-599 - DD-600 - DD-601 - DD-602 - DD-603
18	Cmp	CO-604	NVEC Simulator	Extended NVector Simulator	DD-605 - DD-606 - DD-607 - DD-608 - DD-609
19	Cmp	CO-610	Activity Logger	Provides capabilities for logging UAV related events (such as assigned flights executed missions...)	DD-104 - DD-213 - DD-612 - DD-613 - DD-614 - DD-615 - DD-617 - DD-618 - DD-619 - RE-611 - RE-616
20	Cmp	CO-620	UI Middleware	Provides capabilities for connecting to multiple GCS' sending commands to and receiving messages from UAVs.	DD-117 - DD-18 - DD-19 - DD-20 - DD-21 - DD-22 - DD-421 - DD-622 - DD-623 - DD-624 - DD-625 - DD-627 - DD-629 - DD-631 - DD-632 - DD-633 - DD-635 - DD-636 - DD-638 - DD-640 - DD-764 - RE-108 - RE-110 - RE-626 - RE-628 - RE-630 - RE-634 - RE-637 - RE-639 - RE-9
21	Cmp	CO-641	Vaadin UI	User interface for managing UAVs routes and planning flights.	DD-117 - DD-118 - DD-119 - DD-122 - DD-644 - RE-112 - RE-642 - RE-643
22	Cmp	CO-645	UI Route Assignment	Provides capabilities for selecting existing routes and assigning them to active UAVs	DD-352 - DD-647 - DD-648 - DD-650 - DD-652 - DD-654 - DD-657 - DD-658 - DD-660 - DD-661 - DD-760 - DD-761 - RE-646 - RE-649 - RE-651 - RE-655 - RE-656 - RE-659
23	Cmp	CO-663	UI Route Creation	Provides capabilities for creating new flight routes on a map that are stored in Dronology	DD-168 - DD-421 - DD-665 - DD-667 - DD-669 - DD-671 - DD-673 - DD-674 - DD-675 - DD-676 - DD-678 - DD-762 - DD-767 - RE-664 - RE-666 - RE-668 - RE-670 - RE-672 - RE-677 - RE-679



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