

# EMBRY-RIDDLE

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## Small Unmanned Aircraft System Consumer Guide



June 2016



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*Figure 1. sUAS Consumer Guide Outdoor Operations Research Team and an assortment of examined systems*

## PURPOSE

Within the next year, significant changes to how unmanned aircraft systems (UAS) are used and integrated into the National Airspace System (NAS) are anticipated, including wider application and operation under the [Federal Aviation Administration](#) (FAA)'s *small UAS (sUAS) certification and operation rules* (i.e., [Part 107](#)). With the increased accommodation for sUAS operation, subsequent oversight and tracking, and innovative development, the benefits and utility of these systems will continue to increase, including in the [educational domain](#). Despite recent technological and regulatory advancement, concern for irresponsible [operation](#) of sUAS (55 pounds and under) continues to grow. The projection that more than 2.5 million such platforms are currently operating in the NAS, with [potential growth of up to seven million by 2020](#), has far reaching implications for this evolving, \$100+ million industry. However, by increasing awareness of rules, regulations, and best-practices through expanded public education, such as [Embry-Riddle Aeronautical University](#) (ERAU)'s [UAS workshops](#) and [sponsored-research](#), as well as public service campaigns including [Know Before You Fly](#), critical insight and guidance can reach this new segment of the aviation population.

## Background

While the FAA has actively promoted safety and responsible [operation](#), they cannot reach these new pilots alone; they need the full support of the aviation community. By providing educational information to inexperienced (novice) operators, we can help to increase awareness, while also connecting these fledgling pilots to critical resources and assistance to become responsible stakeholders in our shared community. [ERAU-Worldwide](#) hopes to reach a large and diverse audience with this *Consumer Guide* to help promote thorough platform consideration and comparison prior to purchase and use. In support of this goal, we examined 12 popular consumer multirotor sUAS platforms, reviewing key areas of critical importance to users. These investigation areas, essential to understanding suitability of platforms, included system performance, quality of construction, ease of operation, cost, accuracy of advertised capability, and user support. This *sUAS Consumer Guide* has been prepared to assist a wide variety of users, especially novices, to evaluate options for purchase, appropriate to their skill and experience levels, while introducing key metrics for future consumer sUAS comparison.



Figure 2. Tethered sUAS in flight

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## EVALUATION METHOD

A mixed-methods ([sequential explanatory](#)) research strategy was developed and implemented to examine a series of consumer multirotor sUAS (instruments) and identify suitability as initial platforms for novice operators. The research for this guide began in November 2015, with student teams formed in December. These student teams, under the guidance of ERAU-Worldwide UAS faculty, began collecting published performance (quantitative) data for consumer multirotor sUAS, based on selection criteria. The team generated funds through a [crowdfunding campaign](#), including donations of systems for inclusion in the testing. In March 2016, an sUAS [Operational Test Plan](#), including a rubric for system assessment and testing procedures, was developed and submitted to the *ERAU Safety Review Board* for consideration and approval. In April 2016, the research team met in Daytona Beach, FL to conduct operational assessment of the acquired sUAS, indoors and outdoors (flown under the provisions of the [Nevada Institute of Autonomous Systems](#) [NAIS; FAA designated UAS test site] [public certificate of waiver or authorization](#) [COA]) in accordance with Federal, State, and local regulations. The testing event featured detailed examination of each system; operation as suggested by the manufacturer (operational ease); review of system assembly (construction quality); comparison of published performance to operational experience (availability and accuracy of reported values); and use of available operator support resources (user support).

## Research Statement

This mixed-methods study was designed to examine and identify the suitability of a series of consumer sUAS as initial platforms for novice operators. A [sequential explanatory](#) mixed methods design was employed, with quantitative and qualitative data collected in series, analyzed independently, and then merged for final analysis. For this study, the rationale supporting collection and analysis of both quantitative and qualitative data was the need to compare individual measures representing platform capability (quantitative) with subjective, assessed quality (qualitative) ratings to determine an overall level of platform suitability to an end user, a novice sUAS operator.



*Figure 3. Images from sUAS operational testing event (student simulation testing; Phantom 3 in flight; capturing speed)*

## Measures and Scoring

At the start of this project a series of critical measures were identified to determine overall system performance, applicability, and suitability to a novice operator (pilot). The data associated with these measures were captured through investigation, inspection, and operational testing of each platform. The individual scores from the assessments (quantitative and qualitative) were analyzed to establish a score and ranking for suitability, system performance, and cost-effectiveness. The measurement scores for each system are presented individually in the *Platform Reviews* section, and collectively, sorted by measure, in the *Data Analysis Presentation* section.



### Quantitative Metrics

A series of quantitative measures for each sUAS were captured or derived through investigation and analysis, using publicly available resources and acquired operational systems:

- **Maximum Speed** – greatest speed of the aircraft, measured in knots (kts; not to exceed 87.00); when possible, speed observed from operational testing was used, otherwise published value is presented
- **Endurance** – time the system is able to remain operational and aloft, measured in minutes; when possible, endurance observed from operational testing was used, otherwise published value is presented
- **Payload Capacity** – lifting capability of the platform, over and above components required to operate, measured in pounds (lbs)
- **Camera Quality** – visual sensor capture capability for both video and still imagery, measured in pixels vertical resolution (p) and megapixels (MP)
- **Pricing** – total system cost (not to exceed \$3,500), including all equipment required to operate, second battery, charger, and transport case (excludes cost of a HD camera, if not included)
- **Communication Range** – distance aircraft could travel from handheld control and remain in communication, measured in feet (ft)
- **Utility** - number of identified applications supported; training, aerial filming, research, and recreation
- **Critical Metrics** – availability of the published performance (quantitative) metrics described above, from the manufacturer or other sources

Each quantitative value was used to calculate average performance for all sUAS examined and establish a series of individual quantitative scores. When a value was not available or applicable (N/A), it was treated as a zero (0) in the individual scoring calculations. However, the non-reported values were excluded from calculation of mean (average) scores. Each individual value was compared to the optimal (best performing) and used to determine an individual (weighted) rating score (0-100%) in accordance with the following formula:

$$(\text{Specific Value}_{sUAS} / \text{Optimal Value}_{All\ Systems}) \times 100$$

Pricing required calculating the score relative to a maximum limit of \$3,500:

$$(1 - [\text{Cost}_{sUAS} / 3500]) \times 100$$

**Note:** The term “value,” as used here, represents an actual resultant or published (reported) measurement; “score” represents a percentage, assessed or calculated; and “rating” represents a weighted calculation, based on comparison to an optimal value or score.

The details of the scoring are found under each individual *Platform Review*, as well as the *Data Analysis Presentation* section of this document.

### Qualitative Metrics

The following qualitative measures represent subjective assessment scores captured through inspection, investigation, operational assessment, and analysis, using publicly available resources and acquired operational systems:

- **Construction Quality** - workmanship evident in the construction and assembly of the systems and OEM components
- **Operational Ease** - ability of the system to be operated by a wide range of users from inexperienced novice operators, to experienced and trained pilots

**Note:** Limited automatic (autonomous) functionality was also examined, as it related to operational ease. However, this project did not feature a detailed comparison of such functions, among systems.

- **Availability and Accuracy of Reported Values** - completeness and consistency of published system information, used to analyze and justify selection or use of a platform and perform detailed flight planning and safety analysis
- **User Support** - resources and information available to a user, including documentation, guidance, and online tools

The independent scores for each system measure were used to calculate average (mean) and individual qualitative scores for all of the sUAS examined. Each individual score was compared to the optimal score for the specific measure to calculate an individual (weighted) rating score (0-100%), in accordance with the following formula:

$$(\text{Specific Score}_{\text{sUAS}} / \text{Optimal Score}_{\text{All Systems}}) \times 100$$

The details of the scoring are found under each individual *Platform Review*, as well as the *Data Analysis Presentation* section of this document.

### **Novice Suitability Score**

The *novice suitability score* represents how well the platform supports an inexperienced operator in gaining essential skills and familiarization with the responsible use of a multirotor sUAS, while reducing potential risk and ensuring safe operation. It reflects appropriateness of the platform for a novice, as well as measures of useful functionality and quality. A score for each sUAS was calculated by averaging the individual (weighted) rating scores of those measures (metrics) essential to a users' experience acquiring and operating a system, to determine a mean score, in accordance with the following formula:

$$\Sigma(\text{endurance, camera quality, pricing, construction quality, operational ease, accuracy, user support})_{\text{sUAS Scores}} / n_{\text{measures}}$$

While the other metrics captured and analyzed in this research are useful to identify important capabilities and performance, they were not considered essential to a novice users' experience or fine motor skill development in training or familiarization.

### **Total System Performance Score**

The *total system performance score* represents how well the sUAS performs, compared to the others systems examined in the study; specifically, in regards to all quantitative and qualitative measure scoring. A score was calculated for each system by averaging all of the individual (weighted) rating scores, in accordance with the following formula:

$$\Sigma(\text{maximum speed, endurance, payload capacity, camera quality, pricing, communication range, utility, construction quality, operational ease, accuracy, user support})_{\text{sUAS Scores}} / n_{\text{measures}}$$

This score, does not indicate the strength of a sUAS to support a novice user, but instead, how well the system performs in relation to all investigated measures, which may be useful to the larger sUAS operator community to identify and isolate systems well suited to their own particular needs or desired functions.

**Cost-Effectiveness Score**

The *cost-effectiveness score* represents an assessment of practical return, given the total system cost. Unlike the previous two scoring methods, it represents a ratio, rather than a percentage, which is calculated by dividing the total system cost (*pricing*) by the *system performance*, in accordance with the following formula:

$$(Pricing_{sUAS} / Total\ System\ Performance_{sUAS}) : 1$$

This score provides an indication of how effective an sUAS might be at performing desired functions, given overall cost; the lower the value, the greater the potential effectiveness. This score reflects the cost for each single-percentage of operational performance (e.g., 10:1 equates to each single-percent of performance costing \$10.00).

**System Selection Criteria**

The following requirements were established for selection of the sUAS platforms examined for this *Consumer Guide*:

- Price (less than \$3,500; including all equipment required to operate, second battery, charger, and transport case)
- Platform type (electric, multirotor)
- User replaceable battery
- Aircraft maximum gross takeoff weight (MTOW) of 7.5 pounds or less, including payload
- Wide-scale availability (commercially-off-the-shelf [COTS], online retailers)

**Assumptions**

The following assumptions were made in support of this research:

- sUAS limited to multirotor configurations for consistency and to examine a system type with a rapidly growing users base (future iterations may include fixed-wing, hybrids, and conventional rotary-wing sUAS)
- Availability of a PC, tablet, and/or monitor for display of telemetry or sensor payload data or sUAS control interaction (not included in system pricing)
- Availability of a high-definition (HD) camera (e.g., GoPro) for incorporation into the platform, when stock option not provided or integrated (not included in system pricing; excluded, if system infrastructure did not support signal transmission, receipt, and display)
- Registration and operation of the sUAS in accordance with Federal, State, and local laws, as well as community-based safety practices
- Quantitative data captured and analyzed, prior to collection and analysis of qualitative data
- If a quantitative measure was not applicable or available (i.e., not published; “not reported”), it was treated as a zero (0) in scoring; however, if captured or derived through testing, it was acknowledged in the individual sUAS ratings and reviews (“verified in testing” or “captured in testing”)



Figure 4. Images from sUAS operational testing event (Parrot Bebop 2; Phantom 3; review of XPlorer controls)

## Categories

The following represent the various categories, including number and respective percentage, of those sUAS examined for this *Consumer Guide*:

- **Total Systems:** 12 (100%)
- **Pricing**
  - <\$499: 5 (41.67%)
  - \$500-\$999: 4 (33.33%)
  - \$1,000-\$2499: 2 (16.67%)
  - \$2500+: 1 (8.33%)
- **Weight (MTOW)**
  - <1lbs: 4 (33.33%)
  - 1.1-4.4lbs: 6 (50.00%)
  - 4.4lbs+: 2 (16.67%)
- **Camera-equipped (or supports inclusion)**
  - Yes
    - 2-6 MP: 2 (16.67%)
    - 6-12 MP: 3 (25.00 %)
    - 12.1 MP: 5 (41.67%)
    - Not specified: 1 (8.33%)
  - No: 1 (8.33%)
- **FPV-configured**
  - Yes: 9 (75.00%)
    - WiFi/digital: 9 (75.00%)
    - Ultra (4k): 4 (33.33 %)
    - HD (1080p): 4 (33.33%)
    - SD (720p): 1 (8.33%)
  - No: 3 (25.00%)
- **Utility (Uses)**
  - Training: 12 (100%)
  - Aerial Filming: 8 (66.67 %)
  - Research: 9 (75.00%)
  - Recreation: 12 (100%)



Figure 5. Images from sUAS operational testing event (Bebop 2 launch; assortment of sUAS; Form500 in flight)



## PLATFORM REVIEWS

This section contains the presentation of final findings from system data collection and comparison; each platform is presented in order of *novice suitability*, from most to least.

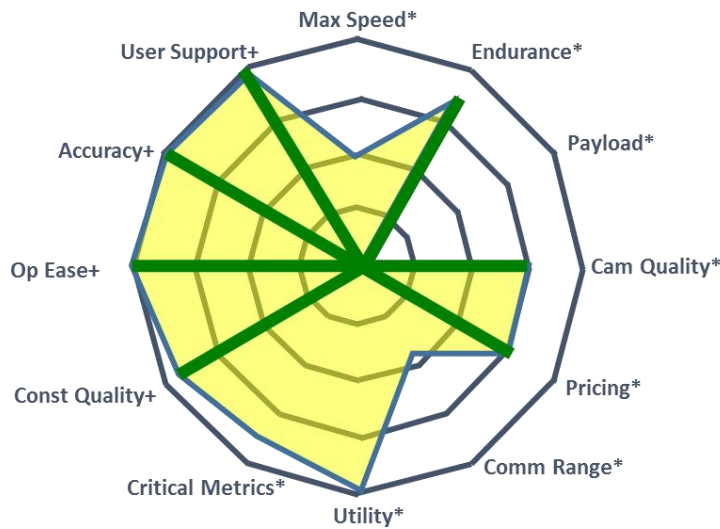
### Parrot Bebop 2

*Novice Suitability Score: 87.95% (1<sup>st</sup> of 12)*

Unsuitable

Ideal

87.95%



*Suitability measures marked in green, all others related to total performance scoring*

### Features

- FPV enabled (WiFi/digital, 2.4GHz and 5GHz streaming to smart-device app)
- 8 GB internal storage
- Fisheye lens and software gimbal for improved stability, reduced mechanical

- complexity, and 90-degree down-look camera capability
- Controllable using *Skycontroller* or smart-device app
- 2,700 milliampere-hour (mAh) battery (also used with *Skycontroller*)

### Ratings

- Max Speed: 26.07 kts (verified in testing; 47.40% score)
- Endurance: 25 mins (83.33% score)
- Payload Capacity: Not reported (0% score)
- Camera Quality: 1,080p and 14 MP (72.75% score)
- Price: \$844.97 (75.86% score)
- Comm Range: 7,392.00 ft (45.16% score)
- Utility: 100% (score) of identified uses
- Critical Metrics: 85.71% (score)

- Construction Quality: 91.64% (score)
- Operational Ease: 100% (score)
- Accuracy: 95.77% (score)
- User Support: 96.33% (score)

**Total Performance Score: 74.50% (6<sup>th</sup> of 12)**

**Cost-effectiveness Score: 11.34:1 (8<sup>th</sup> of 12)**

## Review

The [Parrot Bebop 2](#) earned the highest *novice suitability score*, while also providing the most intuitive user control of all options tested. The results of the operational assessment indicate the *Bebop 2* is a solid, well-rounded choice for novices to gain familiarity with multirotor operation, ensure safety, and support more advanced uses, upon mastery of basic operational skills. The system scored higher than average for *endurance, communication range, utility, construction quality, operational ease* (top score), *accuracy and availability of reported values, and user support*; slightly less than average for *maximum airspeed, camera quality, pricing, and critical metrics*; and less than average for *payload capacity*. It was tested using the [Skycontroller](#), an [iPad mini 2](#) tablet, and the [FreeFlight 3](#) app, which add substantially to the user experience and communication performance. Use of the *Skycontroller* provides excellent controllability and situational awareness (non-distracting to operator), as well as reliable communications to an approximate range of 1.4 miles (7,392 ft; published performance), making the system easy to operate and fun to fly. The *Bebop 2* is highly suited to a novice operator, while also providing features beneficial to advanced users, including [route planning](#) and a [software development kit](#) (SDK) for system programming. It can support a wide variety of applications beyond familiarization, especially aerial filming, research, and training indoors, and to a limited degree, outdoors.

## Strengths

- Simplistic, but reliable and highly-capable design that is easy for novice users to operate and service (maintain/repair); most intuitive user control of all systems tested (100% *operational ease*) that is easy to setup and fun to fly
- Nimble, responsive, and self-correcting in translational flight
- Provided excellent control and situational awareness, when combined with *Skycontroller* and a tablet
- Design offers protection of the integrated camera, which features unique software gimbaling for reduced mechanical complexity and weight-savings
- Small overall footprint, which is useful for indoor operations
- Battery is compatible with both aircraft and *Skycontroller*
- Detailed [documentation](#) provided

## Weaknesses

- Requires smart-device to configure and operate
- Relatively expensive, especially with *Skycontroller* (\$844.97, as configured; 9<sup>th</sup> in cost-effectiveness ranking)
- Four unique rotor blades are both color matched front/rear and feature opposing hub styles; can be confusing to new users and limits possible replacement parts
- Propeller detachment occurred several times during takeoff (minimal safety impact due to small sizing, weight, and inertia); attachment could use improvement
- Maximum speed, MTOW, and small size (reduced VLOS profile) limits outdoor operational range (reduced VLOS profile and increased susceptibility to wind effects)
- Automatic takeoff/landing results in imprecise control; would be better as an option rather than forced requirement (novice users appreciated this feature, while experienced operators prefer more control)
- *Payload Capacity* was not published; assumed to be zero

## Manufacturer Details

Webpage: <http://www.parrot.com/products/bebop2/>

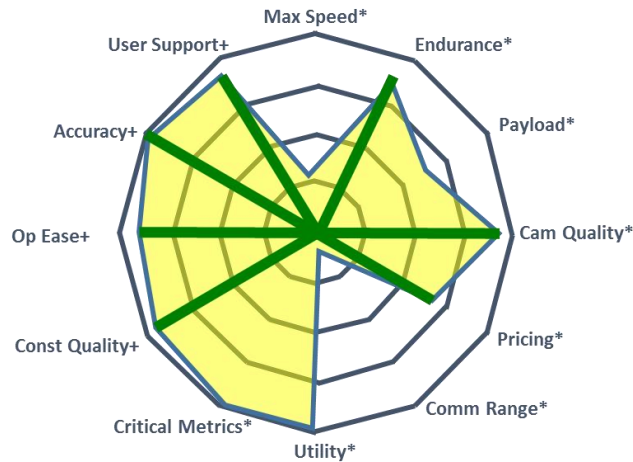
## Yuneec Typhoon 4K

Novice Suitability Score: 86.24 % (2<sup>nd</sup> of 12)

Unsuitable

Ideal

86.24%



Suitability measures marked in green, all others related to total performance scoring

### Features

- FPV enabled (WiFi/digital, 5.8GHz, 720p streaming to controller)
- Handheld controller featuring touchscreen
- Three-axis gimbal and distortion free camera - 4K/30 frame per second (fps) ultra HD video (1080p/120fps slow motion video) and 12 MP imagery
- Includes handheld *SteadyGrip* for use of camera, when not mounted to sUAS
- *WatchMe*, *FollowMe*, and *Return Home* functions
- Geofencing and No Fly Zone
- MicroSD storage (4-128 GB)
- 5,400 mAh battery (3S 11V LiPo)

### Ratings

- Max Speed: 14.78 kts (published; 26.87% score)
- Endurance: 25 mins (83.33% score)
- Payload Capacity: 1.32 lbs (66% score)
- Camera Quality: 4,000p and 12 MP (93.30% score)
- Price: \$1099.98 (68.57% score)
- Comm Range: 1,200.00 ft (7.33% score)
- Utility: 100.00% (score) of identified uses
- Critical Metrics: 100.00% (score) available
- Construction Quality: 90.59% (score)
- Operational Ease: 85.44% (score)
- Accuracy: 92.90% (score)
- User Support: 89.54% (score)

**Total Performance Score: 75.32%**  
(4<sup>th</sup> of 12)

**Cost-effectiveness Score: 14.60:1**  
(10<sup>th</sup> of 12)



### Review

The [Yuneec Typhoon 4K](#) earned the second-highest *novice suitability score*, receiving consistent marks across the individual measures. The operational assessment results indicate the *Typhoon* is an exceptionally well-rounded and constructed option to gain familiarity with multirotor operation, ensure safety, and support more advanced uses, upon mastery of basic operational skills. The system scored higher than average for *endurance, payload capacity, camera quality, utility, critical metrics, construction quality, operational ease, availability and accuracy of reported values, and user support*; and less than average for *maximum airspeed* (intentionally governed by manufacturer; can be released), *pricing, and communication range*. All equipment required to operate the system is included, as purchased, and the pricing is consistent with other high-quality and capable systems. Additionally, the controller provides an excellent ergonomic design to support use of advanced features, without the need to purchase and incorporate a smart-device (e.g., smartphone or tablet), and the system is capable of carrying a user-configured payload. The sUAS automatically prevents operation within four-miles from national aviation authority designated [No-Fly Zones](#) or above the designated 400 ft above ground level (AGL) ceiling. However, the manufacturer has provided some users with a means to unlock these limits, if they are able to properly demonstrate appropriate FAA approval (e.g., [COA](#) or [Section 333 Grant of Exemption](#)). The *Typhoon 4K* is very appropriate to a novice operator, while also providing advanced features and capabilities useful to more experienced operators, especially to those planning outdoor operations in support of aerial filming, training, or research.

### Strengths

- Ready to fly with full system functionality, as purchased (smart-device not needed)
- Lightweight, given all the provided capabilities
- High degree of stability, even with GPS disabled and placed in *Angle* mode; very quiet in operation
- Excellent ergonomics, well thought out design of controller (e.g., placement and function of engine start, photo, and video buttons, rate and gimbal sliders, and touchscreen), as well as integration of components (smart-device not required for full operational functionality)
- Solid performer regarding endurance (25 min), pricing (\$1,099.98), utility, critical metrics, construction quality, operational ease, accuracy, and user support
- Battery warning features tactile shaking of the controller, as well as visible alert
- Detailed [documentation](#) provided

### Weaknesses

- Apparent that weight was a consideration in design, as construction material of some elements (e.g., gimbal and camera housing) appears very fragile
- No obvious provisions for significant maintenance or repair of components
- Indoor operations required disabling GPS and flying in *Angle mode* (not recommended by Manufacturer, results in reduced stability)
- Control movements result in audible alerts, which can be confusing to a new user
- Landing can be problematic, as the aircraft rises and falls (i.e., pogo's) several times before finally settling on the ground
- *No-Fly Zone* feature helps novices, but substantially limits advanced users

### Manufacturer Details

Webpage: [http://www.yuneec.com/products/aerialuav/q500\\_4k](http://www.yuneec.com/products/aerialuav/q500_4k)

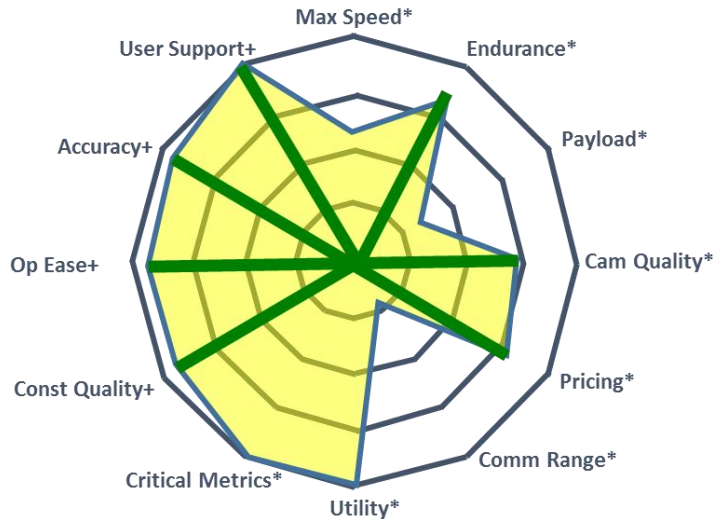
## DJI Phantom 3 (Standard)

Novice Suitability Score: 86.19% (3<sup>rd</sup> of 12)

IMPERFECT

IDEAL

86.19%



Suitability measures marked in green, all others related to total performance scoring

### Features

- FPV enabled (WiFi/digital, 2.4GHz, 720p streaming to smart-device app)
- Automatic flight assistance, including auto-hover, No Fly Zone, and geofencing
- Live GPS map, HD video display, camera controls, and simulator on *DJI Go* app (smart-device)
- Three-axis gimbal and camera (f/2.8 aperture) – 2.7K/30fps HD video and 12 MP imagery
- Ergonomic, lightweight controller with smartphone mount and built-in WiFi (.62 mile range)
- MicroSD storage
- 4,480 mAh Intelligent Flight battery (4S 15.2V LiPo)

### Ratings

- Max Speed: 31.10 kts (published; 56.55% score)
- Endurance: 25 mins (83.33% score)
- Payload Capacity: 0.66 lbs (33.00% score)
- Camera Quality: 1,080p and 12 MP (69.28% score)
- Price: \$777.00 (77.80% score)
- Comm Range: 3,273.60 ft (20.00% score)
- Utility: 100% (score) of identified uses
- Critical Metrics: 100% (score) available
- Construction Quality: 90.43% (score)
- Operational Ease: 91.31% (score)
- Accuracy: 92.17% (score)
- User Support: 99.05% (score)

**Total Performance Score: 76.08%**  
**(3<sup>rd</sup> of 12)**

**Cost-effectiveness Score: 10.21:1**  
**(7<sup>th</sup> of 12)**

### Review

The [DJI Phantom 3 \(Standard\)](#) is a flexible and adaptable sUAS with excellent handling characteristics, functionality, and substantial user base, achieving a *novice suitability score* within a .05% margin of the second-highest scoring system. It received high marks across many of the individual measures, indicating the *Phantom 3* is a very well-rounded and constructed option to gain familiarity with multirotor operation, ensure safety, and support more advanced uses, upon mastery of basic operational skills. The system scored higher than average for *maximum speed, endurance, pricing (less-expensive), utility, critical metrics, construction quality, operational ease, availability and accuracy of reported values, and user support*; but less than average for *payload capacity, camera quality, and communication range*. This system provides the ability to interface a personal smart-device, using the [DJI Go](#) app, to unlock additional capabilities and advanced features, and the system is capable of carrying a user-configured payload. There are some significant limitations associated with use of this system that must fully be considered, especially by advanced operators. First, it requires user registration and update of firmware to operate the system (necessitating internet access and creation of a personal account). Secondly, it automatically prevents operation in those areas designated as [No Fly Zones](#) by the manufacturer, even when authorized to do so through appropriate FAA approval (e.g., [COA](#) or [Section 333 Grant of Exemption](#)). The *Phantom 3 (Standard)* represents an affordable option that is very appropriate for a novice operator, while also providing advanced features and capabilities, accessible through the *DJI Go* app and smart-device, that are useful to more experienced users. It is well suited for those planning to conduct operations both indoors and outdoors, in support of aerial filming, training, or research, as long as those activities are outside of specified DJI [No Fly Zones](#). A mechanism for accommodation of FAA operational approval would increase the outdoor usability of this system.

### Strengths

- Majority of construction exhibits solid workmanship
- Aircraft setup is very intuitive (software is a challenge)
- Excellent stability and responsiveness; easy to control and recover (some minor trim and position hold, when operated indoors); sufficient thrust kept in reserve to power out of many issues
- Excellent documentation and support available (concise, easy to understand); large user community
- No perceivable lag between aircraft and smart-device (*DJI Go* app)
- Power level indicator on battery
- Detailed [documentation](#) provided with a large [user community](#)

### Weaknesses

- Requires smart-device to configure and operate
- *DJI Go* app requires substantial user review to ensure all modes and settings are correctly configured; presents additional complication to a novice operator
- System requires registration with DJI, prior to initial flight
- Controller lacks clear labelling of controls, many important control functions need to be accessed through smart-device; integration of elements and app was overly complicated, compared to other systems
- Construction of controller, including smartphone clip, appears of lower quality than that of the aircraft
- *No Fly Zone* feature helps novices, but substantially limits advanced users who may have appropriate authorization to fly in an area (automatically prevents flight)

### Manufacturer Details

Webpage: <http://www.dji.com/product/phantom-3-standard>



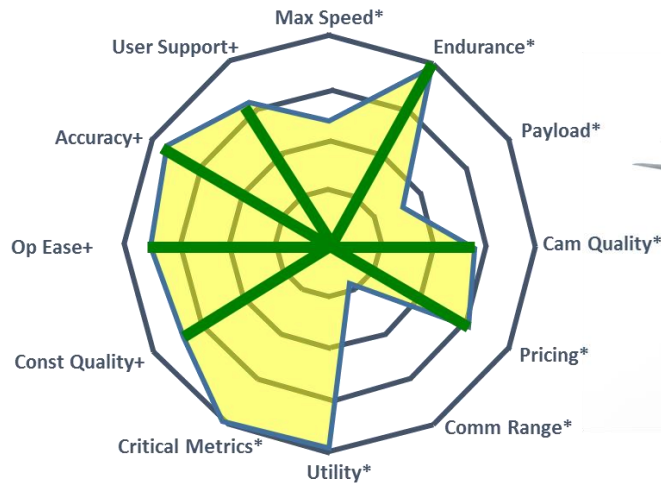
## Hubsan X4 Pro

Novice Suitability Score: 82.61% (4<sup>th</sup> of 12)

Unsuitable

Ideal

82.61%



Suitability measures marked in green, all others related to total performance scoring

### Features

- FPV enabled (WiFi/digital, 5.8GHz streaming to controller)
- 2.4/5.8GHz transceiver with integrated 7-inch touchscreen Android tablet
- Actual Direction Control, GPS, Altitude, and Return to Home operational modes and a programmable Waypoints system

- Three-axis gimbal and 1080p HD camera
- MicroSD storage
- Three Return to Home fail-safes
- Optional OEM parachute recovery system available
- 7,000 mAh battery (3S 11.1V LiPo)

### Ratings

- Max Speed: 32.46 kts (verified in testing; 59.02% score)
- Endurance: 30 mins (100% score, maximum)
- Payload Capacity: 0.80 lbs (40% score)
- Camera Quality: 1,080p and 12.2 MP (69.64% score)
- Price: \$879.97 (74.86% score)
- Comm Range: 3,281.00 ft (20.05% score)
- Utility: 100% (score) of identified uses
- Critical Metrics: 100% (score) available

- Construction Quality: 82.47% (score)
- Operational Ease: 85.57% (score)
- Accuracy: 90.43% (score)
- User Support: 75.29% (score)

**Total Performance Score: 74.78%**  
(5<sup>th</sup> of 12)

**Cost-effectiveness Score: 11.77:1**  
(9<sup>th</sup> of 12)

### Review

The [Hubsan X4 Pro \(Deluxe\)](#) is a robust and rugged system with excellent redundancy, a wide range of advanced capabilities, professional appearance, and substantial endurance (30 min; published). The X4 Pro received above average scores across many of the individual measures, indicating the system is a cost-effective and well-packaged option to gain familiarity with multirotor operation, ensure safety, and support more advanced uses, upon mastery of basic operational skills. The system scored higher than average for *maximum speed, endurance (top scorer), utility, critical metrics, constructional quality, operational ease, and availability and accuracy of reported values*; but less than average for *payload capacity, camera quality, pricing, communication range, and user support*. The documentation provided with the system was limited and spread across several manuals. The user base has not yet been established online, which in the future may help with diagnosing common issues or challenges. All equipment required to operate the system is included, as purchased, and the pricing is lower than other similar systems. The controller provided with the Deluxe version features one of the most professional appearances of all those tested and the system is capable of carrying a user-configured payload, as well as an [OEM parachute recovery system](#). However, the system also presents users with some challenges that could be better addressed by the manufacturer, including the need to power-down the integrated tablet and controller separately, difficulty viewing screen in sunlight (even with sunshade), and complex camera communication configuration. The X4 Pro is appropriate for a novice operator, but it may be beneficial to seek assistance from a more experienced operator to configure and setup the system for the first time. It also provides additional features and capabilities that may be useful to advanced operators, such as those planning to conduct operations both indoors and outdoors, in support of aerial filming, training, or research.

### Strengths

- Ready to fly with full system functionality, as purchased
- Very robust system, high quality construction and rugged durability
- Impressive control setup, very professional appearance with functions clearly labelled
- Included high-quality HD camera and gimbal
- Triple-redundant fail-safe options and availability of an OEM parachute recovery system
- Detailed [documentation](#) provided (video instructions are a good supplement, but should not be used as a primary documentation source)

### Weaknesses

- User must turn ON/OFF discrete elements of controller (controller, tablet, etc.); may present too much complication for a first time user
- Difficult to configure component interfaces (e.g., camera to controller)
- Camera payload is slung very low and close to the ground and has separate power control (button)
- Sunlight makes display screen difficult to read, even with provided sunshade
- Some construction material is questionable (e.g., battery door); designed less for maintenance, repair, or access
- Controller (touchscreen transceiver) and [aircraft](#) information presented in two separate documents; primary document depicts stock controller option (not touchscreen)

### Manufacturer Details

Webpage: <http://www.hubsanx4pro.com>

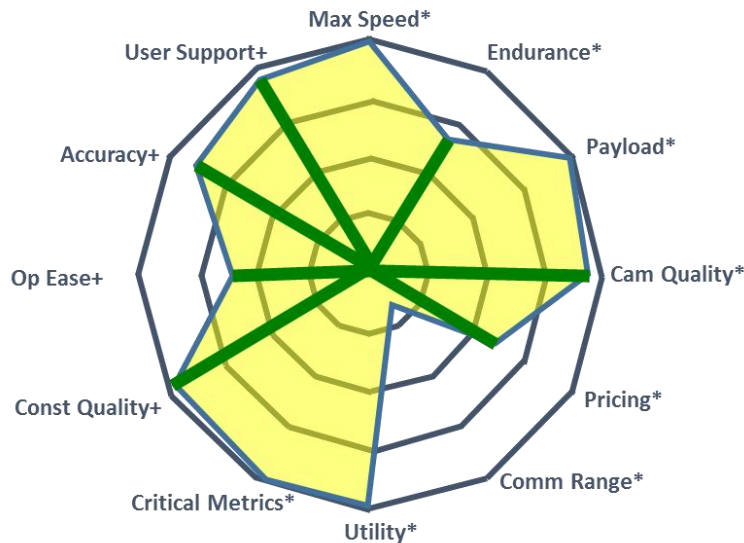
## 3D Robotics Solo

Novice Suitability Score: 80.27% (5<sup>th</sup> of 12)

Unsuitable

Ideal

80.27%



Suitability measures marked in green, all others related to total performance scoring

### Features

- FPV enabled (WiFi/digital, 5.8GHz, 720p streaming to smart-device app)
- Multiple operational modes (CableCam, Orbit, Follow, Selfie, Pano, Zipline, user-defined geofencing, automatic takeoff/landing, and Return to Home)
- Standalone flight simulator app available
- HD video streaming, smart shot panning and one-touch control, real-time airspace safety information, and recording to smart-device camera roll
- Flyaway warranty protection
- Three-axis gimbal and GoPro integration, as priced (available without; camera not included)
- 5,200 mAh Smart battery (4S 14.8V LiPo)

### Ratings

- Max Speed: 55 kts (published; 100% score, maximum)
- Endurance: 20 mins (66.67% score)
- Payload Capacity: 1.95 lbs (97.5% score)
- Camera Quality: 4,000p and 12 MP (93.3% score)
- Price: \$1361.85 (61.09% score)
- Comm Range: 2,640.00 ft (16.13% score)
- Utility: 100% (score) of identified uses
- Critical Metrics: 100% (score) available
- Construction Quality: 95.36% (score)
- Operational Ease: 59.45% (score)
- Accuracy: 89.19% (score)
- User Support: 96.84% (score)

**Total Performance Score: 81.29%**  
**(1<sup>st</sup> of 12)**

**Cost-effectiveness Score: 16.75:1**  
**(11<sup>th</sup> of 12)**



## Review

The [3D Robotics Solo](#) is a professional and adaptable system, designed for outdoor operation with excellent stability and automatic functionality, programmability, and camera control for aerial filming. It received high scores across many of the individual measures, indicating the *Solo* is a solid option for more experienced users to conduct outdoor multirotor operations, ensure safety, and support more advanced uses, upon mastery of basic operational skills. The system scored higher than average for *maximum speed* (top scorer), *endurance*, *payload capacity*, *camera quality* (using separately purchased GoPro), *utility*, *critical metrics*, *construction quality*, *accuracy and availability of reported values*, and *user support*; but less than average for *pricing* (more-expensive), *communication range*, and *operational ease* (being limited to only outdoor operations significantly affected this score). The controller provides for very comfortable operation of the system, can be combined with a smart-device, and is one of the best designed and intuitive camera controls (paddle) of all the systems examined; the system is also capable of carrying a user-configured payload. It should be noted that the inability to operate the system indoors (in accordance with manufacturer instructions) limits the usability for novice and advanced users and is inconsistent with similar systems; this substantially affected *operational ease* scoring. The *Solo* can be an appropriate choice for novice operators planning to use it outdoors and under the supervision and assistance of an experienced operator. It also provides very advanced features and capabilities, supported through a smart-device (*3DR Solo app*), for experienced users looking to perform aerial filming, training, or research.

## Strengths

- Well constructed, compact design, very visually appealing
- Most robust gimbal of all systems tested
- Controller was very comfortable; very intuitive camera control through vertical paddle switch
- Stable in flight
- Easy to maintain and configure
- Excellent [documentation](#) with a large [user community](#)

## Weaknesses

- Requires smart-device to access full system functionality
- Cannot be flown indoors (3DR Solo [user manual](#) states “Don’t fly Solo indoors,” p. 25)
- High performance capability and responsiveness may not be ideal for a novice operator (responsiveness can be adjusted)
- Complex to operate (controllability challenging; difficult to land), when GPS positioning is not enabled
- 3DR Solo app appears more complex than comparable smart-device apps with some indicators being difficult to read (with exception of battery remaining, which was clear and conveniently located)
- Firmware is continually updated (impacts the accuracy of printed documentation)

## Manufacturer Details

Webpage: <https://3dr.com/solo-drone/>

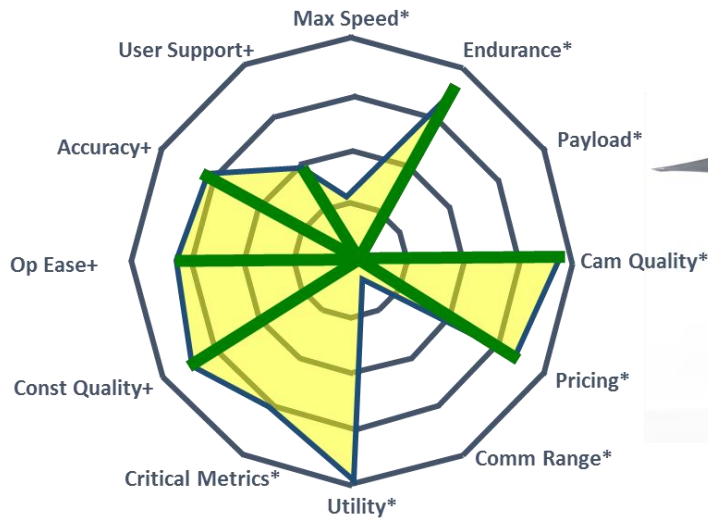
## Xiro XPlorer G

Novice Suitability Score: 78.36% (6<sup>th</sup> of 12)

Unsuitable

78.36%

Ideal



Suitability measures marked in green, all others related to total performance scoring

### Features

- FPV enabled (WiFi/digital, 5.8GHz, 720p streaming to smart-device app)
- Three-axis gimbal and 1080p HD/14.4MP camera with polarized lens
- Features Actual Directional Control, Follow Me, Circle Me, Return to Home, waypoint following, and GPS flight modes
- Supports GoPro 3/4
- 5,200 mAh battery (3S 11.1V LiPo)

### Ratings

- Max Speed: 18.38 kts (verified in testing; 33.42% score)
- Endurance: 25 mins (83.33% score)
- Payload Capacity: Not reported (0% score; tested with GoPro [.22 lb])
- Camera Quality: 4,000p and 12 MP (93.3% score)
- Price: \$613.65 (82.47% score)
- Comm Range: 1,640.00 ft (10.02% score)
- Utility: 100% (score) of identified uses
- Critical Metrics: 85.71% (score) available
- Construction Quality: 85.91% (score)
- Operational Ease: 79.9% (score)
- Accuracy: 74.84% (score)
- User Support: 48.8% (score)

**Total Performance Score: 64.81%**  
**(7<sup>th</sup> of 12)**

**Cost-effectiveness Score: 9.47:1**  
**(6<sup>th</sup> of 12)**

### Review

The [Xiro XPlorer G](#) is a robust, well constructed, and capable system, with a highly professional appearance. The system's scores across many of the individual measures indicate it can be useful in conducting multirotor operations, ensuring safety, and supporting more advanced uses. The *XPlorer G* scored higher than average for *endurance*, *camera quality* (using separately purchased *GoPro*), *pricing* (less-expensive), *utility*, *construction quality*, and *operational ease*; slightly less than average for *critical metrics*; and less than average for *maximum speed*, *payload capacity* (not reported), *communication range*, *accuracy and availability of reported values*, and *user support*. The system was very responsive (overly, except in yaw), presenting a challenge to inexperienced operators during takeoff, translational and pattern flight, and landing. The system is also capable of carrying a user-configured payload, but configuration and setup with a [GoPro](#) and [Xiro](#) app was also overly complicated for new users and difficult to diagnose, using the available support materials. Given the observations from the assessment, the *XPlorer G* would be less appropriate to a novice operator, unless operated under direct supervision and assistance of an experienced operator. Its advanced features and capabilities, accessible and supported using a smart-device and app, can be very useful in support of indoor or outdoor aerial filming, training, or research operations.

### Strengths

- Very robust system, high quality construction and durability
- High degree of capability, given the cost to comparable systems
- Operational control was intuitive, if not slightly too responsive (nimble) for a novice operator

### Weaknesses

- Requires smart-device to access full system functionality
- Difficulty in configuring camera interface (lack of documentation to diagnose issue); could not control camera through Android app
- Outward folding legs present an area of concern (landing with drift may collapse leg; features a small, unstable footprint)
- Observed a fair amount of drift and attitude loss in translational flight; extremely low yaw rate
- Larger smart-phones do not fit the slide-out holder on the controller
- [Documentation](#) is minimal; too much information presented in complicated infographic format, which makes it difficult to locate specific information
- *Payload Capacity* was not published, but tested with GoPro weighing .22 lb

### Manufacturer Details

Webpage: <http://www.xirodroneusa.com>

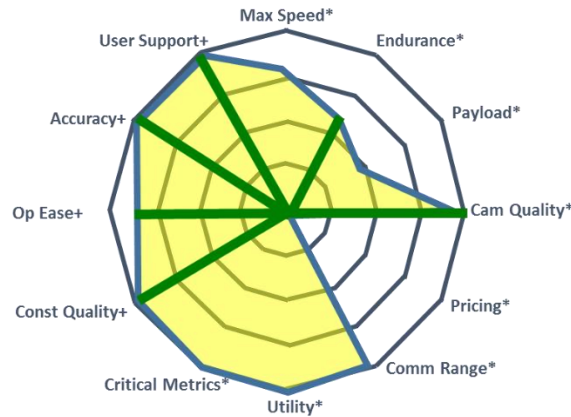
## DJI Inspire 1

Novice Suitability Score: 77.79% (7<sup>th</sup> of 12)

IMPERFECT

77.79%

IDEAL



Suitability measures marked in green, all others related to total performance scoring

### Features

- FPV enabled (WiFi/digital, 5.8GHz, 720p streaming to smart-device app)
- Aerodynamic, transforming design, featuring intelligent power management and visual/ultrasonic positioning systems
- Automatic flight assistance (auto-hover, No Fly Zone, and geofencing)
- Live GPS map, HD video display, camera controls, and simulator on DJI Go app (smart-device)
- Zenmuse three-axis gimbal and camera – 4K/30fps HD video and 12 MP imagery
- Ergonomic control featuring multiple user operation, smart-device mounting, and built-in WiFi (3.1 mile range)
- MicroSD storage
- 4,480 mAh Intelligent Flight battery (4S 15.2V LiPo)

### Ratings

- Max Speed: 42.76 kts (published; 77.75% score)
- Endurance: 18 mins (60% score)
- Payload Capacity: 1.03 lbs (51.5% score)
- Camera Quality: 4,000p and 12.76 MP (94.65% score, maximum)
- Price: \$3421 (2.26% score)
- Comm Range: 16,368.00 ft (100% score, maximum)
- Utility: 100% (score) of identified uses
- Critical Metrics: 100% (score) available
- Construction Quality: 100% (score; maximum)
- Operational Ease: 87.63% (score)
- Accuracy: 100% (score; maximum)
- User Support: 100% (score)

**Total Performance Score: 81.15% (2<sup>nd</sup> of 12)**

**Cost-effectiveness Score: 42.16:1 (12<sup>th</sup> of 12)**



## Review

The [\*DJI Inspire 1\*](#) is an extremely well designed, constructed, and packaged system that sets the standard for “prosumer” sUAS. The *Inspire’s* high scores across most of the individual measures indicate it can be very useful for conducting outdoor multirotor operations, ensuring safety, and supporting more advanced uses. The system scored higher than average for *maximum speed*, *camera quality* (top scorer), *communication range* (top scorer), *utility*, *critical metrics*, *construction quality*, *operational ease*, *availability and accuracy of reported values*, and *user support* (top scorer); and less than average for *endurance*, *payload capacity*, and *pricing* (most-expensive). As with other DJI products, it provides the ability to interface a personal smart-device (using [\*DJI Go\*](#) app to unlock additional capabilities and advanced features) and the system is capable of being configured to carry other payloads, including an [infrared camera produced in partnership with FLIR](#). This system also presents some significant limitations, such as required user registration, mandatory update of firmware (requires user internet access and creation of a personal account), and inability to be operated in areas designated by the manufacturer as [\*No Fly Zones\*](#) (even when authorized to do so through appropriate FAA approval). The *Inspire* is a very high-performance, professional option, but it is not an ideal system for a novice operator due to its size, power, weight, and inertial potential (presents a safety risk). If operated by a inexperienced pilot, experience should first be gained using simulation and smaller, less capable platforms, and then under the direct supervision and combined control (i.e., dual control) of an experienced operator. This system provides very advanced features and capabilities, useful for outdoor operations in support of aerial filming, training, or research, as long as those activities are outside of specified DJI [\*No Fly Zones\*](#). A mechanism for accommodation of FAA operational approval, would increase the outdoor usability of this system.

## Strengths

- Very robust system, high quality construction and durability (highest scoring construction quality)
- Good controllability (and beginner mode) and responsiveness
- Repeat use exhibits practicality of many design features
- First “prosumer” sUAS introduced to the market
- Power level indicator on battery
- High degree of [documentation](#) and [support](#) (100% critical metrics identified, accuracy, and support); as with the *DJI Phantom 3* there is a large [user community](#)

## Weaknesses

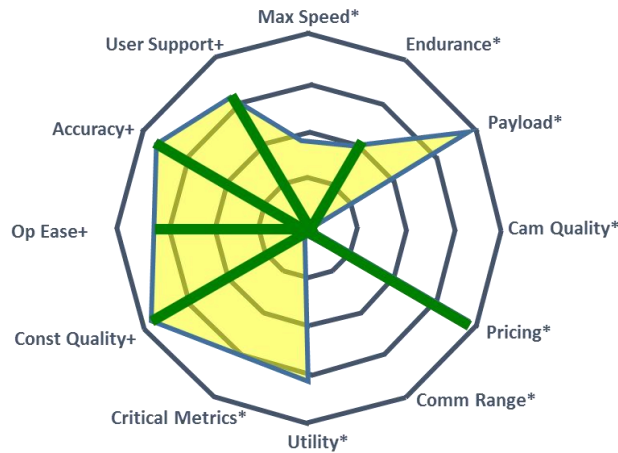
- Requires smart-device to access full system functionality
- May be too advanced for a novice operator, potential exists for safety issues; high degree of potential inertia and performance can result in situations beyond the capability of novice operators (brief distraction can result in disorientation and loss of control)
- *DJI Go* app requires substantial user review to ensure all modes and settings are correctly configured; presents additional complication for a novice
- Elevated rotor configuration provides excellent stability and visibility, but it also subjects the camera payload to a higher degree of risk given a malfunction
- Requiring battery installation to change landing gear configuration (gear down) creates a potential safety issue (need to install, remove, and then reinstall)

## Manufacturer Details

Webpage: <http://www.dji.com/product/inspire-1>

## Helimax Form500 Utility Drone

Novice Suitability Score: 67.41% (8<sup>th</sup> of 12)



Suitability measures marked in green, all others related to total performance scoring

### Features

- Tactic TTX810TS radio system
- 2lbs payload capacity
- Actual Direction Control and Intelligent orientation control featuring Return to Home, Headless, Altitude hold, GPS lock, and auto-landing

### Ratings

- Max Speed: 26.07 kts (not reported, captured in testing; 47.40% score)
- Endurance: 15 mins (50.00% score)
- Payload Capacity: 2.00 lbs (100% score, maximum)
- Camera Quality: N/A (0% score)
- Price: \$362.97 (89.63% score)
- Comm Range: Not reported (0% score; geofence is capable to 820.21 ft)
- Utility: 75.00% (score) of identified uses
- Critical Metrics: 71.43% (score)

- Camera mount and two-axis gimbal (aftermarket camera and FPV equipment purchased separately)
- 5,000 mAh battery (3S 11.1 V LiPo)

- Construction Quality: 90.21% (score)
- Operational Ease: 75.85% (score)
- Accuracy: 86.45% (score)
- User Support: 79.74% (score)

**Total Performance Score: 63.81%**  
**(8<sup>th</sup> of 12)**

**Cost-effectiveness Score: 5.69:1**  
**(4<sup>th</sup> of 12)**

### Review

The [\*Helimax Form500 Utility Drone\*](#) is an excellent payload carrying option, providing a rugged, durable, user customizable design. The system's scores across many of the individual measures indicate it can be useful in conducting outdoor multirotor operations, ensuring safety, and supporting more advanced uses, once it has been custom configured by the user. The system scored higher than average for *payload capacity* (top scorer), *pricing* (less-expensive), *construction quality*, *operational ease*, and *user support*; slightly less than average for *maximum speed*; and less than average for *endurance*, *camera quality* (no interface provided, even when using separately purchased camera), *communication range* (not reported), *utility* (limited without camera functions), *critical metrics*, and *accuracy and availability of reported values*. The *Form500* is less appropriate to a novice operator, unless configured, setup, and operated under the direct supervision and assistance of an experienced operator. It can provide advanced functionality and capabilities, through third-party add-ons, which can make the platform useful for indoor or outdoor operations in support of aerial filming, training, or research.

### Strengths

- Very robust system with good lifting capability and durability
- Use of physical orientation indicators (on front legs) is a good alternative to LEDs (reduces complexity)
- Aircraft is highly user serviceable
- Extremely quiet in flight, despite size

### Weaknesses

- No camera, gimbal, or software included; FPV setup requires purchase and configuration of an aftermarket system
- Overly sensitive (indoors) and required calibration with every flight (suggest removal of propellers during calibration); takeoff required high throttle setting; novice operators will be challenged to operate, especially in combination with any camera functionality
- Low yaw rate, controllability and responsiveness provide a challenge when flying in a pattern
- Very flimsy main body cover constructed of thin plastic and battery connector should be reinforced to maintain longterm durability
- Generic hobby-grade controller, lacked labels making advanced operation difficult (assignment appeared arbitrary and non-intuitive)
- Battery placement can be imprecise, causing CG issue (should include a physical stop or mark)
- [Documentation](#) was minimal, lacking detail of other systems; [controller](#) and [aircraft](#) information presented in two separate documents
- *Maximum Speed* was not published, but a speed of 26.07 kts was captured in testing
- *Communication Range* not published, but default geofence is set to a range of 820.21 ft

### Manufacturer Details

Webpage: <http://www.helimaxrc.com/quadcopters/hmxe0863-form500/index.html>

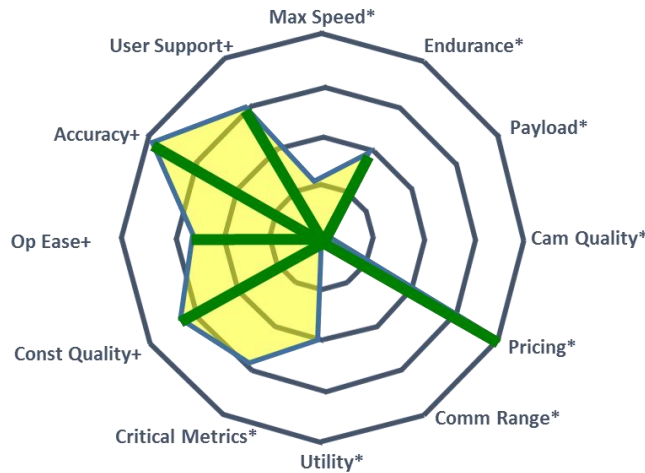
## Dromida Vista UAV

Novice Suitability Score: 65.94% (9<sup>th</sup> of 12)

Unsuitable

65.94%

Ideal



Suitability measures marked in green, all others related to total performance scoring

### Features

- FPV/smartphone version available
- Three-axis gyroscopes and accelerometers
- Durable plastic airframe designed to survive everyday crashes with ease
- Controller featuring Secure Link Technology (SLT), dual rates, four flight modes (Easy,

- Normal, Advanced and Expert), and automatic-flip and digital trim buttons
- Sound and light cues to simplify setup, confirm settings and provide alerts
- 850 mAh battery (3.7V LiPo) and USB charger

### Ratings

- Max Speed: 14.77 kts (not reported, captured in testing; 26.85% score)
- Endurance: 15 mins (50% score)
- Payload Capacity: Not reported (0% score)
- Camera Quality: N/A (0% score)
- Price: \$103.96 (97.03% score)
- Comm Range: 328.08 ft (2.00% score)
- Utility: 50% (score) of identified uses
- Critical Metrics: 71.43% (score) available
- Construction Quality: 79.38% (score)

- Operational Ease: 62.89% (score)
- Accuracy: 94.86% (score)
- User Support: 77.39% (score)

**Total Performance Score: 50.99%**  
**(11<sup>th</sup> of 12)**

**Cost-effectiveness Score: 2.04:1**  
**(1<sup>st</sup> of 12)**



### Review

The *Dromida Vista UAV* is a simple, highly responsive, and affordable option for a novice operator, but it does not provide useful function beyond multirotor familiarization or recreation, reducing its overall suitability. The system scored higher than average for *pricing* (less-expensive), as well as *accuracy and availability of reported values*; slightly less than average for *operational ease* and *user support*; and less than average for *maximum speed*, *endurance*, *payload capacity* (not reported), *camera quality* (no camera), *communication range*, *utility*, *critical metrics*, and *construction quality*. The *Vista's* small size and relatively fast speed (observed, not published by manufacturer) make it a challenge for inexperienced users to control. However, its responsive and high speed performance make it enjoyable to fly recreationally, while its durability helps ensure a quick recovery after a crash. Additionally, it can be charged using a USB adapter. Despite the low *novice suitability score*, this system may be worth considering for basic skills development, based on its low cost (most *cost-effective*) and simplicity.

### Strengths

- Most cost-effective system (2.04:1) and features a durable, crash-resistant construction
- Good accommodation for users of varying levels; basic represents a good compromise between agility and stability, while advanced settings are very aggressive
- Acceptable level of [documentation](#), given capability and cost
- Ready to operate, as purchased

### Weaknesses

- Reduced operational range due to communication range and size (limits VLOS)
- Very easy to overcompensate in control, can rapidly lose control if not experienced
- Minimal stability augmentation or advanced functionality
- Heavily affected by winds or moving air (e.g., air conditioning)
- System more on the “toy” spectrum, rather than functional sUAS
- Maximum Speed not published, but speed of 14.77 kts was captured in testing
- *Payload Capacity* not published and camera not included with system (*Camera Quality*), as tested; camera version (FPV) is available

### Manufacturer Details

Webpage: <http://www.dromida.com/drones/dide03xx-vista-uav/index.php>

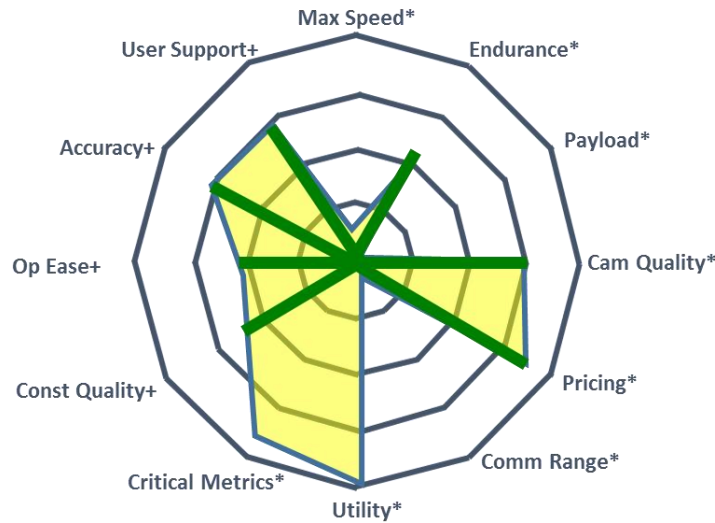
## Elanview Cicada

Novice Suitability Score: 65.65% (10<sup>th</sup> of 12)

Unsuitable

65.65%

Ideal



Suitability measures marked in green, all others related to total performance scoring

### Features

- FPV enabled (WiFi/digital, streaming to smart-device app)
- Built-in GPS and barometer functions for precise control and monitoring of position and altitude
- 169° fisheye lens camera with a fixed F2.8 aperture; adjusted from 0-15° manually or by adjusting flight attitude
- Electronic Image Stabilizing (EIS) system, cushioned camera mount and vibration-

- dampening rubber grommets keep image quality high and details sharp
- Videos are stored in high-definition 1080p, while photos are stored as 16 MP images
- Simple onscreen controls and three operational modes (Key, Joystick, and Gravity)
- 1,000 mAh battery (2S 7.2 V LiPo)

### Ratings

- Max Speed: 6.95 kts (verified in testing; 12.64% score)
- Endurance: 15 mins (50% score)
- Payload Capacity: Not reported (0% score)
- Camera Quality: 1080p and 16 MP (75.98% score)
- Price: \$389.97 (88.86% score)
- Comm Range: 328.08 ft (2.00% score)
- Utility: 100% (score) of identified uses
- Critical Metrics: 85.71% (score) available

- Construction Quality: 54.49% (score)
- Operational Ease: 50.69% (score)
- Accuracy: 70.78% (score)
- User Support: 68.72% (score)

**Total Performance Score: 54.99%**  
**(9<sup>th</sup> of 12)**

**Cost-effectiveness Score: 7.09:1**  
**(5<sup>th</sup> of 12)**

### Review

The [Elanview Cicada](#) is a compact, uniquely designed option featuring a high quality camera. The system's scores across many of the individual measures indicate it could be useful in conducting outdoor multirotor operations, ensuring safety, and potentially supporting more advanced uses. The system scored higher than average for *camera quality*, *pricing* (less-expensive), and *utility*; slightly less than average for *critical metrics*; and less than average for *maximum airspeed*, *endurance*, *payload capacity* (not reported), *communication range*, *construction quality*, *operational ease*, *availability and accuracy of reported values*, and *user support*. Despite the cost-effectiveness score of 7.21:1, the *Cicada* represents a relatively expensive option, given its performance and difficult operation, that could be appropriate to a novice operator if it provided better controllability. Its dependency on use of a smart-device and the [Elanview](#) app as the only control mechanism make it a challenge to operate for both inexperienced and experienced users. Inclusion of a more robust hardware control option and higher quality construction materials, would make this system much more applicable to supporting aerial filming, research, training, and recreation.

### Strengths

- Small size, easily transported design
- High quality camera, given price
- Able to launch with minimal setup

### Weaknesses

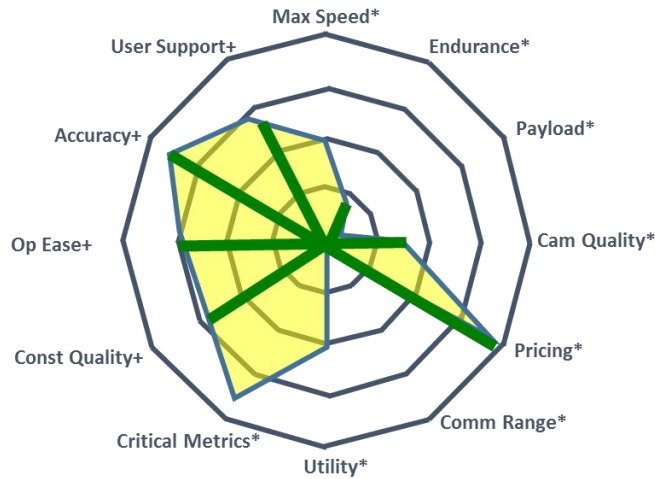
- Requires smart-device to configure and operate
- Reduced operational range due to communication range and size (limits VLOS)
- Low quality (low durability) construction material, may not support long duration use (lowest assessed construction quality of all systems tested; 54.49%)
- High Center-of-Gravity and unconventional design with blades mounted on bottom substantially impacts performance; can come into contact with grass or debris on the ground and significantly affected by wind
- Smart-device interface, made control difficult and frustrating for both novice and experienced users (tried both iOS and Android; users need to constantly look down to confirm contact, no tactile feedback; latency and intermittent throttle control experienced during operation); hardware control option would be desirable
- Lowest published (5.4 kts) and observed (6.95 kts) *Maximum Speed* of all systems tested
- [Documentation](#) is not optimal, lacking of detail
- *Payload Capacity* was not published; assumed to be zero

### Manufacturer Details

Webpage: <http://www.elanviewusa.com>

## Syma X8C Venture

Novice Suitability Score: 63.28% (11<sup>th</sup> of 12)



Suitability measures marked in green, all others related to total performance scoring

### Features

- FPV enabled (WiFi/digital, 2.4 GHz streaming to smartphone app)
- Six-axis gyroscope
- 360-degree eversion (roll) and headless operational modes
- Blade protectors included
- Spread spectrum, 2.4 GHz control and smartphone app
- 2,000 mAh battery (2S 7.4V LiPo)

### Ratings

- Max Speed: 25.86 kts (not reported, captured in testing; 47.02% score)
- Endurance: 7 mins (23.33% score)
- Payload Capacity: 0.18 lbs (9% score)
- Camera Quality: 720p and 2 MP (38.89% score)
- Price: \$138.79 (96.03% score)
- Comm Range: 328.08 ft (5% score)
- Utility: 50% (score) of identified uses
- Critical Metrics: 86.71% (score)
- Construction Quality: 64.95% (score)
- Operational Ease: 67.01% (score)
- Accuracy: 84.54% (score)
- User Support: 68.18% (score)

**Total Performance Score: 53.06% (10<sup>th</sup> of 12)**

**Cost-effectiveness Score: 2.62:1 (3<sup>rd</sup> of 12)**



### Review

The [Syma X8C Venture](#) is a highly cost-effective alternative to more expensive systems, but its inherent low quality and functional limitations prevent useful function beyond multirotor familiarization or recreation, reducing its overall *novice suitability score*. The *X8C Venture* scored higher than average for *pricing* (less-expensive); slightly less than average for *maximum speed* (observed), *critical metrics*, and *operational ease*; and less than average for *endurance*, *payload capacity*, *camera quality*, *communication range*, *utility*, *construction quality*, *availability and accuracy of reported values*, and *user support*. The system requires a substantial time commitment to complete platform assembly and battery charging (approx. 3+ hours), with a very short operational endurance time (7 minutes). The quality of the *X8C Venture's* construction and documentation is more consistent with that of a toy than a sUAS. Additionally, the provided [Syma FPV](#) smartphone app is very simplistic with significant latency, but it could provide novices with a good opportunity to understand how such apps work (e.g., WiFi configuration and use) prior to conducting operations on more complicated and expensive systems. The *X8C Venture* represents a simple, low-cost option that can be appropriate to a novice operator and provides a stable and cost-effective analog to costly, similarly sized systems (e.g., *DJI Phantom 3*). However, the short endurance, quality of construction, and overly simplified smartphone app limit the functionality to multirotor familiarization or recreation. Despite the low *novice suitability score* and other performance ratings, this system may be worth considering for basic skills development, based on its low cost, simplicity, stable flight characteristics, and size.

### Strengths

- Very cost-effective system with similar sizing to other popular consumer multirotors
- Well suited to a beginner with stable flight, simple video app, and durability (especially landing gear)
- Large size, provides a good, low cost training option before committing to a more expensive and capable system

### Weaknesses

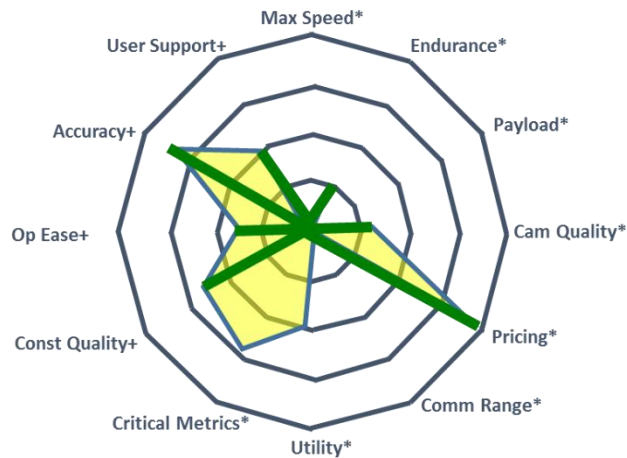
- Requires smart-device to access full system functionality
- Lowest reported payload capacity of all systems tested (.18 lbs)
- Low quality construction and substantial assembly required
- Poor battery performance; 7 min endurance and requires 200 minute charge time (published)
- Smartphone app is very simplistic, which can be good for beginners, but very limiting for experienced operators (high degree of latency exhibited; minimal functionality or data display including lack of platform battery level)
- Substantially affected by wind
- [Documentation](#) was not detailed; consistent with “toy”
- *Maximum Speed* not published, but speed of 25.86 kts captured in testing

### Manufacturer Details

Webpage: <http://www.symatoys.com/product/show/1923.html>

## Dromida Kodo

Novice Suitability Score: 52.63% (12<sup>th</sup> of 12)



Suitability measures marked in green, all others related to total performance scoring

### Features

- Video and imagery recorded to onboard MicroSD
- Three-axis gyroscopes and accelerometers
- Rugged, crash-resistant molded plastic airframe
- Controller featuring Secure Link Technology (SLT), dual rates, three flight modes (Easy, Normal, and Expert), and automatic-flip and digital trim buttons
- Digital camera that shoots 780x480 .avi video and 1.2MP still photos in jpeg format
- 2 GB MicroSD memory card and card reader
- 390 mAh battery (3.7V LiPo) and USB charger

### Ratings

- Max Speed: Not reported (0% score)
- Endurance: 6 mins (20% score)
- Payload Capacity: Not reported (0% score)
- Camera Quality: 480p and 1.2 MP (31.01% score)
- Price: \$83.97 (97.6% score)
- Comm Range: 164.04 ft (1.00% score)
- Utility: 50% (score) of identified uses
- Critical Metrics: 71.43% (score)
- Construction Quality: 61.17% (score)
- Operational Ease: 35.05% (score)
- Accuracy: 78.28% (score)
- User Support: 45.32% (score)

**Total Performance Score: 40.9%**  
**(12<sup>th</sup> of 12)**

**Cost-effectiveness Score: 2.05:1**  
**(2<sup>nd</sup> of 12)**

### Review

The *Dromida Kodo* is a simple, micro-sized system that represents a very affordable option to a novice operator, but it does not provide useful function beyond multirotor familiarization or recreation, making its overall suitability low. The system scored higher than average for *pricing* (less-expensive; top-scorer) and *accuracy and availability of reported values*; and less than average for *maximum speed* (not reported or observed), *endurance*, *payload capacity* (not reported), *camera quality*, *communication range*, *utility*, *critical metrics*, *construction quality*, *operational ease*, and *user support*. While the system does provide for video and imagery capture, it is stored locally, only accessible after the flight, and the quality of the content is very low. The *Kodo's* extremely small aircraft and controller sizing, limited range, and instability make it a challenge for inexperienced users to operate, especially in moving air (e.g., wind or air conditioning). Despite these shortcomings, the system is the least expensive option, has the second-best *cost-effectiveness score*, can be charged using a USB adapter, and can provide enjoyable flight indoors, once responsiveness of the aircraft control has been mastered.

### Strengths

- Durable construction
- Some accommodation for users of varying levels; basic represents a compromise between agility and stability, while advanced settings are very aggressive
- Acceptable level of [documentation](#), given capability and cost
- Ready to operate, as purchased

### Weaknesses

- Very easy to overcompensate in control, can rapidly lose control if not experienced; difficult for a novice to operate
- Miniature controller can be useful for portability, but present a challenge for users
- Substantially reduced operational range due to communication range and micro size (limits VLOS); very easy to lose communication link
- Does not feature any observable stability augmentation
- Heavily affected by moving air (e.g., winds or air conditioning)
- Lowest reported endurance, MTOW, communication range, and camera quality of all systems tested (6.00 minutes, .11 lbs, 164.04 ft, and 480p/1.2 MP)
- Lowest assessed operational ease and user support of all systems tested (35.05% and 45.32%)
- System is more of a “toy,” rather than functional sUAS
- *Maximum Speed* and *Payload Capacity* (assumed to be zero) not published

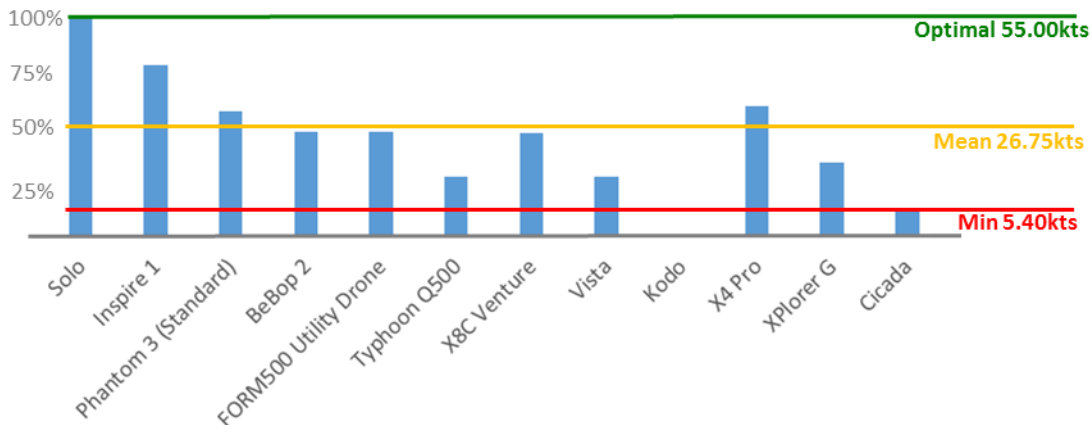
### Manufacturer Details

Webpage: <http://www.dromida.com/drones/dide0005-kodo/index.php?setlang=en>

## DATA ANALYSIS PRESENTATION

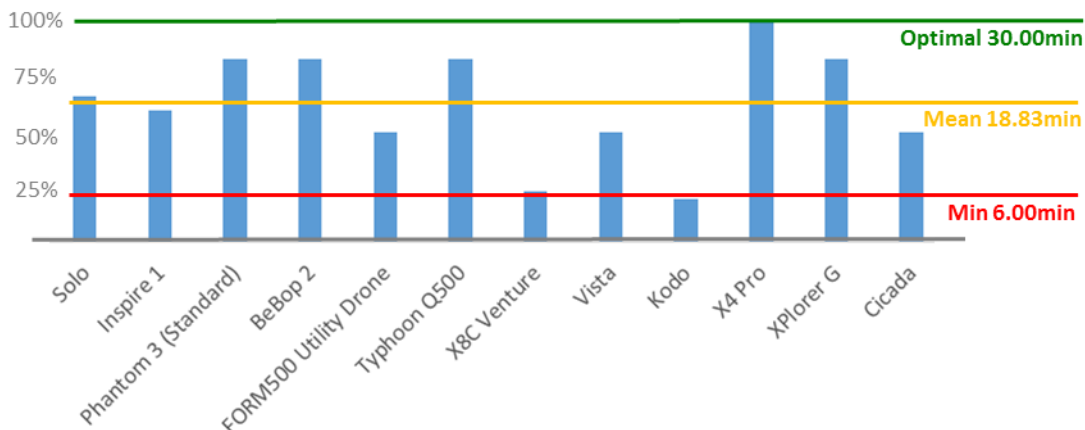
This section contains the results of the data analysis, including identification of *mean* (marked in orange), *optimal* (green), and lower boundary (*min*; red) for each measure and sUAS. This information can help readers to better understand performance of individual systems, in relation to the areas examined in this study. It may also be useful in supporting comparative analyses, prior to in-depth investigation or acquisition of individual platforms, based on needs or requirements not addressed in this research.

### Maximum Speed



- Sample size ( $n$ ) = 11 (11 observed; 91.67% of  $N$ )
- Optimal value: 55.00 kts (100% rating score; maximum)
- Minimum value: 5.40 kts (9.82% rating score)
- Mean value: 26.75 kts (48.63% rating score)

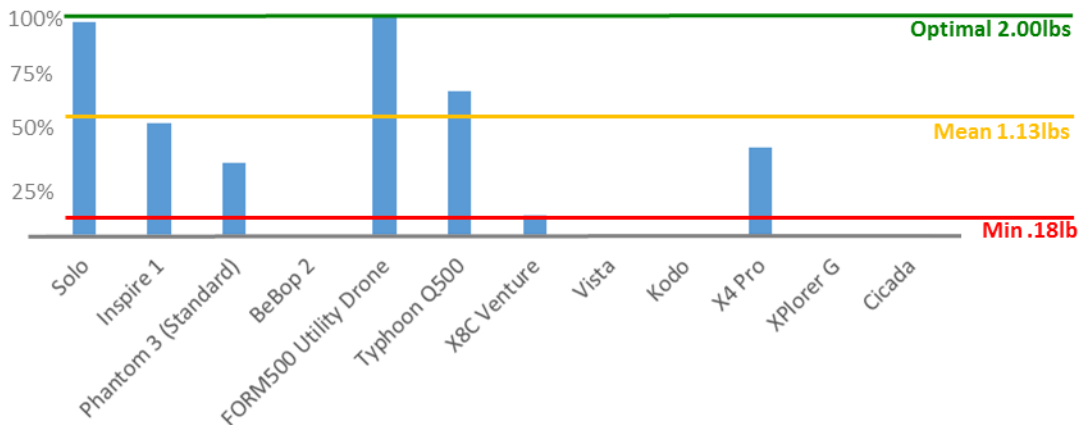
### Endurance



- Sample size ( $n$ ) = 12 (100% of  $N$ )
- Optimal value: 30.00 minutes (100% rating score; maximum)
- Minimum value: 6.00 minutes (20.00% rating score)
- Mean value: 18.83 minutes (62.78% rating score)

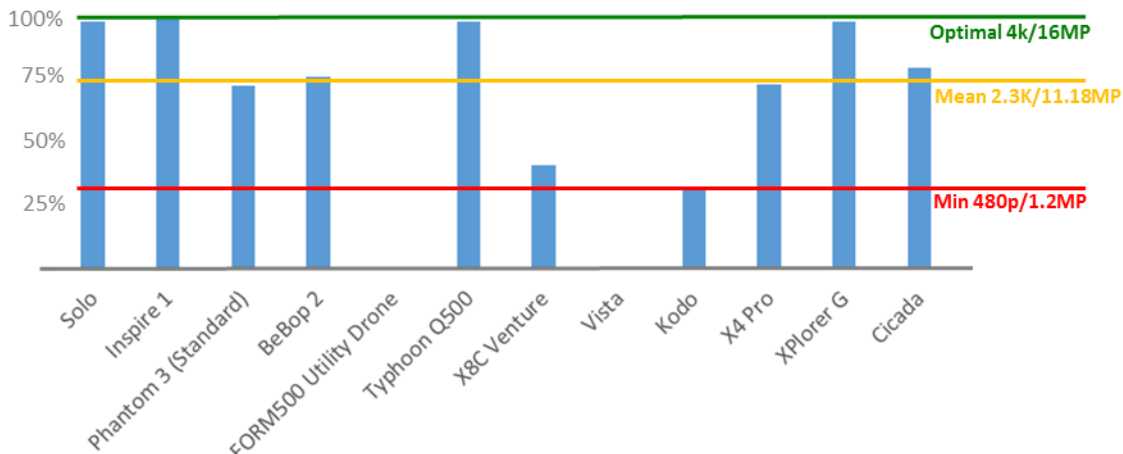


## Payload Capacity



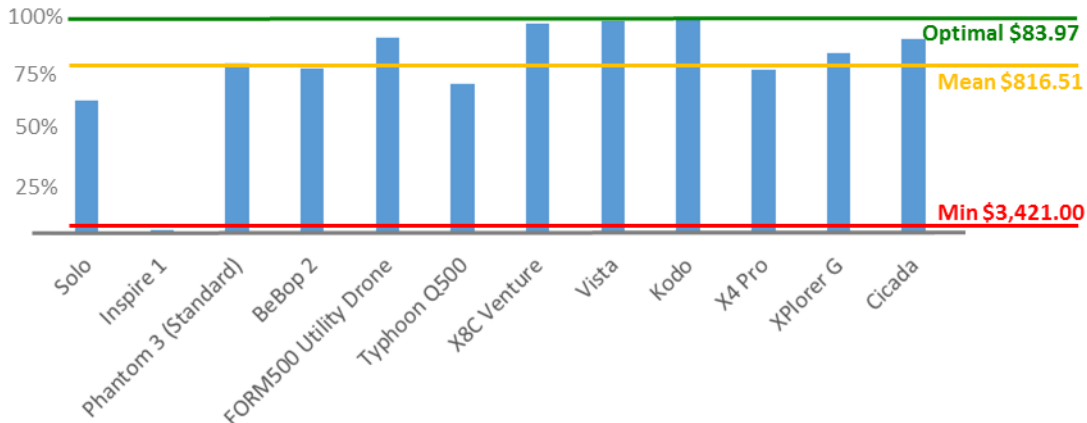
- Sample size ( $n$ ) = 7 (58.33% of  $N$ )
- Optimal value: 2.00 lbs (100%; maximum)
- Minimum value: .18 lbs (9.00% rating score)
- Mean value: 1.13 lbs (56.71% rating score)

## Camera Quality



- Sample size ( $n$ ) = 10 (83.33% of  $N$ )
- Optimal value: 4,000p and 16 MP (100%; maximums)
- Minimum value: 480p and 1.2 MP (31.01% rating score)
- Mean value: 2,320p and 11.18MP (73.21% rating score)

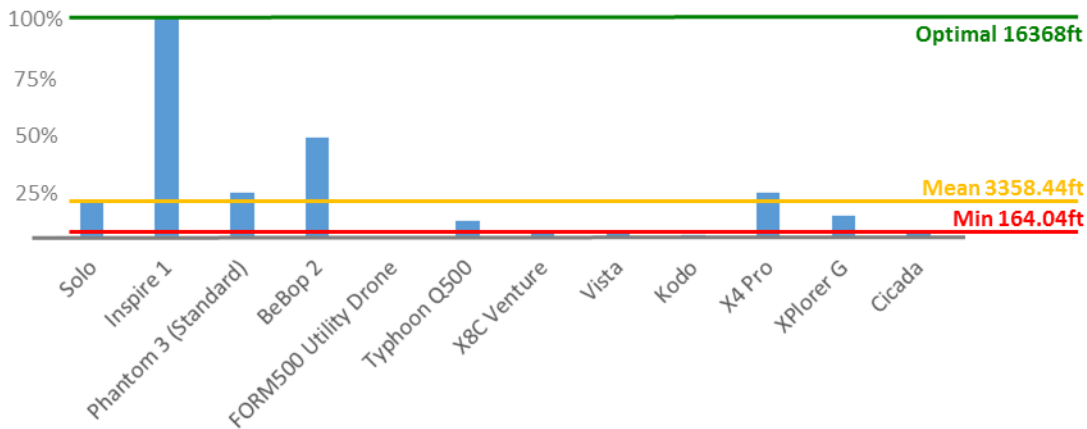
## Pricing



- Sample size ( $n$ ) = 12 (100% of  $N$ )
- Optimal value: \$83.97 (97.60% rating score; minimum price)
- Maximum value: \$3,421.00 (2.26% rating score)
- Mean value: \$839.84 (76.00% rating score)

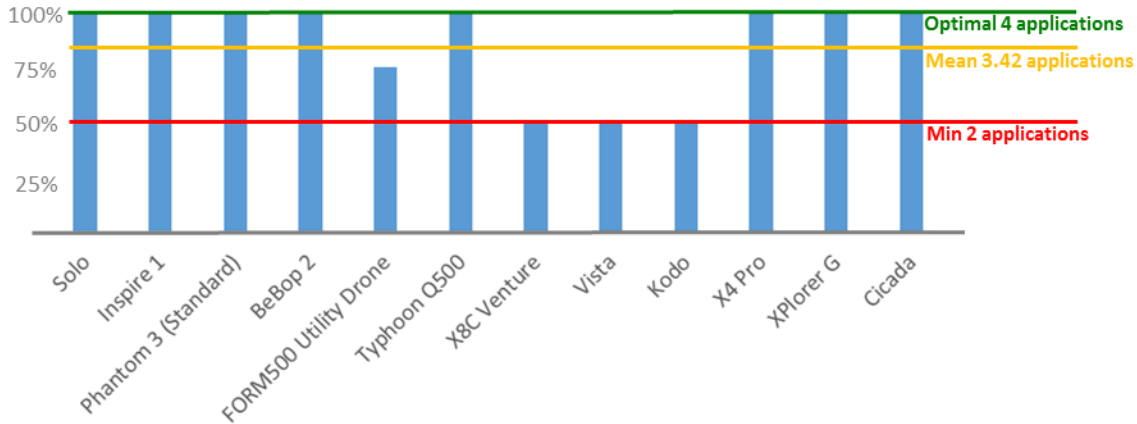
**Note:** Pricing values are subject to rapid change, based on market conditions, demand, and sales; presented values are based on cost of system, as determined at time research was conducted.

## Communication Range



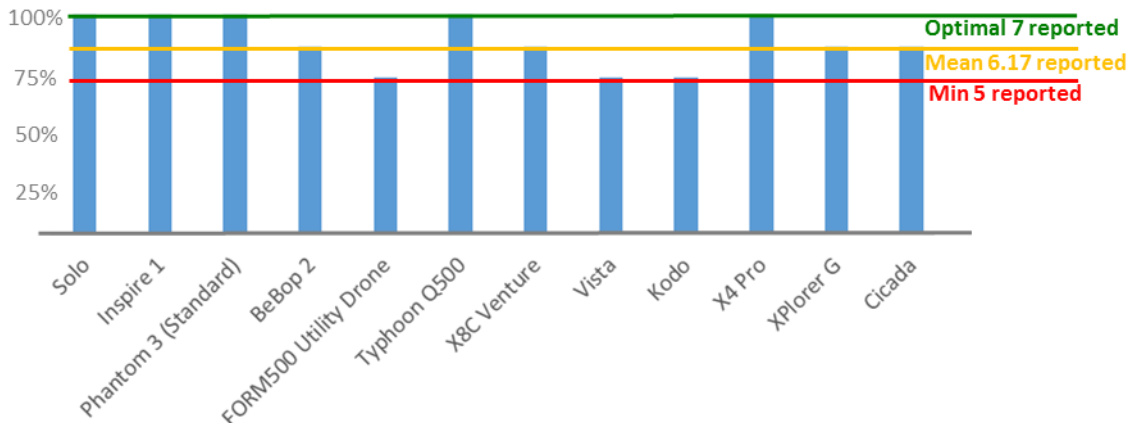
- Sample size ( $n$ ) = 11 (91.67% of  $N$ )
- Optimal value: 16,368.00 ft (100% rating score; maximum)
- Minimum value: 164.04 ft (1.00% rating score)
- Mean value: 3,358.44 ft (20.52% rating score)

## Utility



- Sample size ( $n$ ) = 12 (100% of  $N$ )
- Optimal value: four (100% rating score; maximum)
- Minimum value: two (50.00% rating score)
- Mean value: 3.42 applications (85.42% rating score)

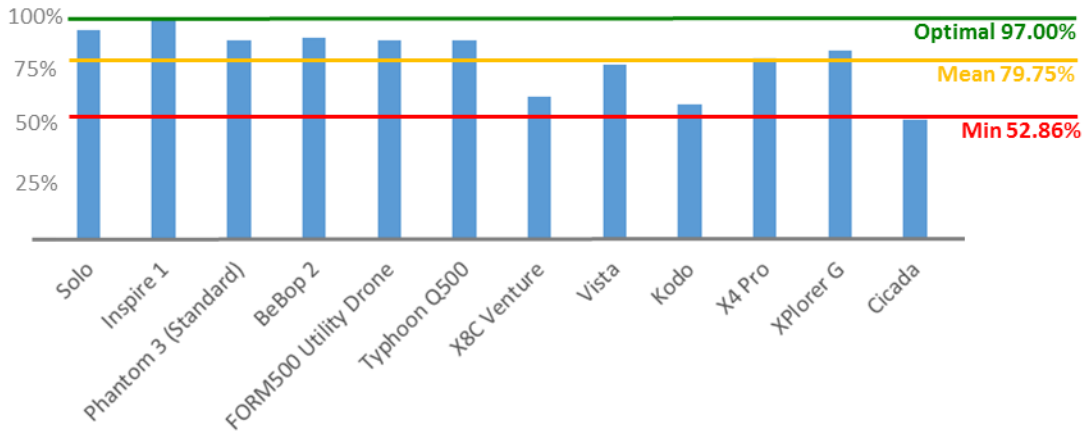
## Critical Metrics



- Sample size ( $n$ ) = 12 (100% of  $N$ )
- Optimal value: seven reported (100% rating score; maximum)
- Minimum value: five reported (71.43% rating score)
- Mean value: 6.17 reported (88.10% rating score)

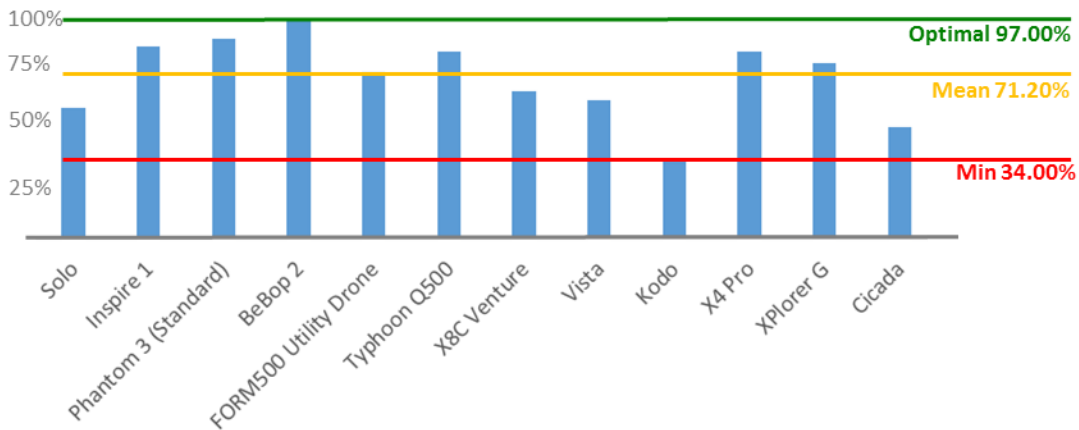
**Note:** There is an observable lack of standardization among information provided by manufacturers; primarily, availability of maximum speed (66.67% reported) and payload capacity (58.33% reported), two critical parameters required for acquisition evaluation (purchase), flight planning, and safety analysis; communication range was reported at 91.67%, while all others were reported at 100%

## Construction Quality



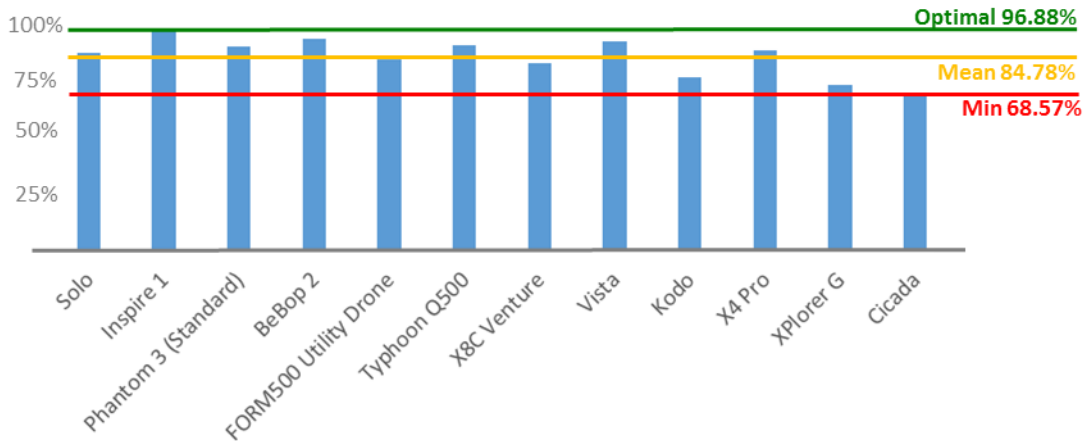
- Sample size ( $n$ ) = 12 (100% of  $N$ )
- Optimal score: 97.00% assessment (100% rating score; maximum)
- Minimum score: 52.86% assessment (54.49% rating score)
- Mean score: 79.75% assessment (82.22% rating score)

## Operational Ease



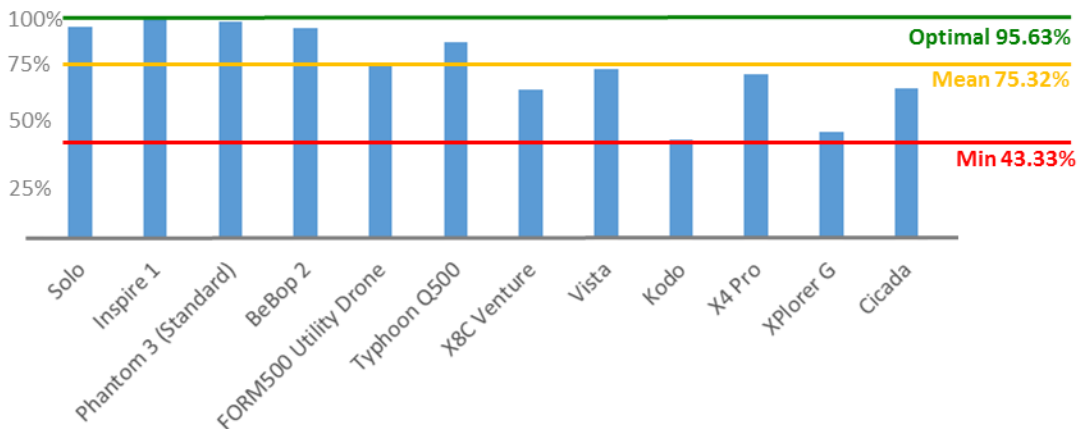
- Sample size ( $n$ ) = 12 (100% of  $N$ )
- Optimal score: 97.00% assessment (100% rating score; maximum)
- Minimum score: 34.00% assessment (35.05% rating score)
- Mean score: 71.20% assessment (73.40% rating score)

## Accuracy and Availability



- Sample size ( $n$ ) = 12 (100% of  $N$ )
- Optimal score: 96.88% assessment (100% rating score; maximum)
- Minimum score: 68.57% assessment (70.78% rating score)
- Mean score: 84.78% assessment (87.52% rating score)

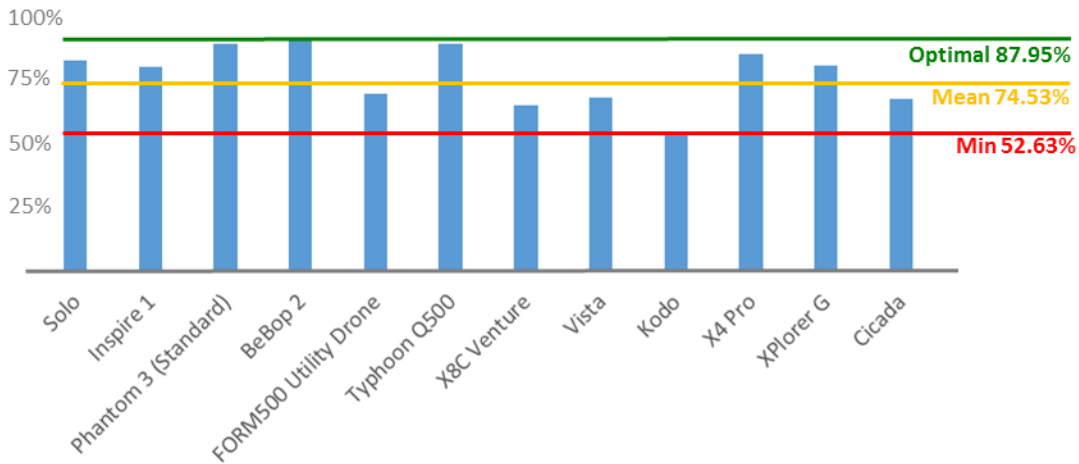
## User Support



- Sample size ( $n$ ) = 12 (100% of  $N$ )
- Optimal score: 95.63% (100% rating score; maximum)
- Minimum score: 43.33% assessment (45.32% rating score)
- Mean score: 75.32% assessment (78.77% rating score)

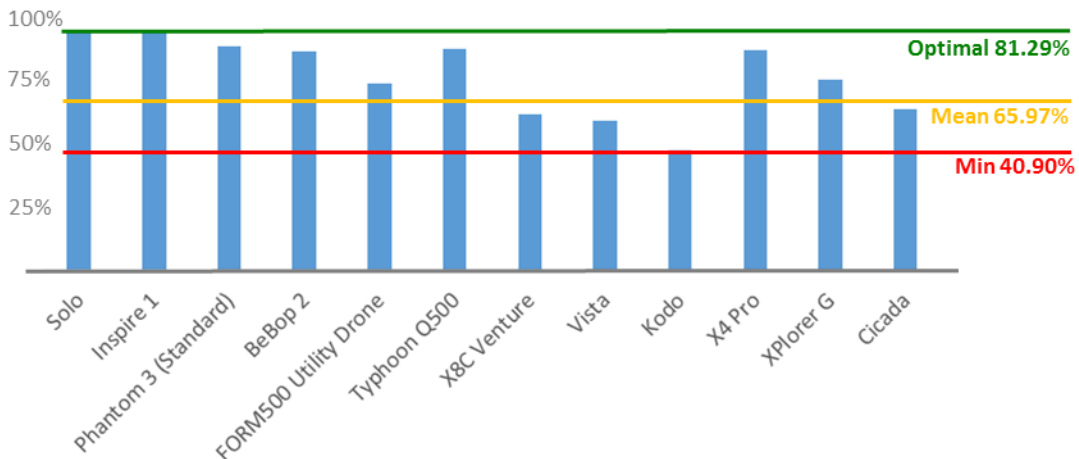


## Novice Suitability



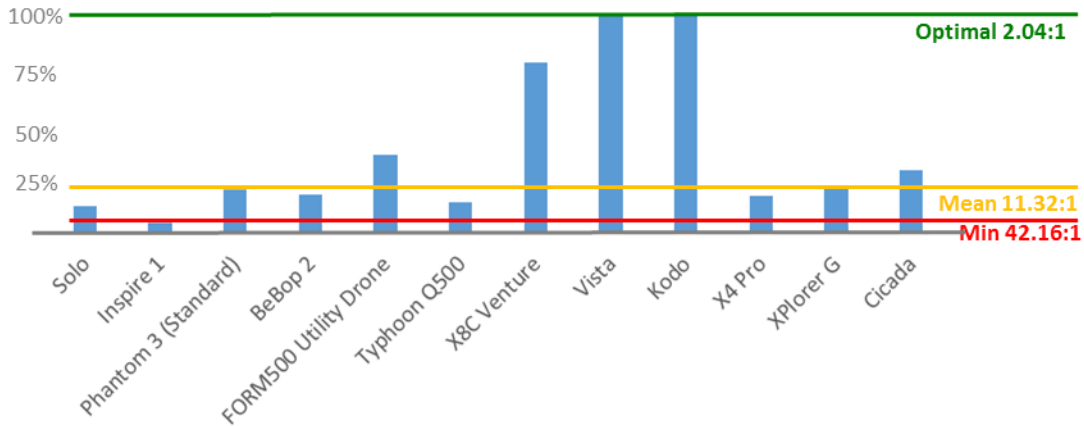
- Sample size ( $n$ ) = 12 (100% of  $N$ )
- Optimal rating score: 87.98%
- Minimum rating score: 52.63%
- Mean rating score: 74.53%

## Total System Performance



- Sample size ( $n$ ) = 12 (100% of  $N$ )
- Optimal rating score: 81.29%
- Minimum rating score: 40.90%
- Mean rating score: 65.97%

## Cost-effectiveness



- Sample size ( $n$ ) = 12 (100% of  $N$ )
- Optimal ratio: 2.04:1 (100% rating score)
- Minimum ratio: 42.16:1 (4.84% rating score)
- Mean ratio: 11.32:1 (18.02% rating score)

## RECOMMENDATIONS

### System Evaluation Considerations

Many aspects of suitable sUAS selection can be derived from the individual categories and assessments provided in this study. Besides those specific ratings presented, readers can also assess the importance of individual aspects as they relate to their envisioned operation or application. While there are substantial differences in performance, costs, other measured characteristics of the investigated systems, there are also significant variation among incorporated technologies and designs, which may drive acquisition decisions. These differences may range from the obvious, such as inclusion of (or provision for) a sensor and/or camera system, to less obvious applicable control and stability logic incorporated in a system. Furthermore, there is an evident shift in technology level (and also price point) noticeable in the incorporation of flight control and navigation augmentation. With a higher level of flight control and navigation technology comes a fundamentally different orientation of platform purpose, design, and programmability. In general, highly augmented systems emphasize stability in operation, as a sensor platform, over other considerations, while less augmented systems tend to cater more to recreational use and operator engagement (e.g., flying for fun). Appropriate system selection should always include consideration of purpose.

A few less obvious differences in flight control logic that were observed during testing included inertia compensation and drift, descend control, and ground effect handling. There were notable differences in the distances that systems continued to drift from a rapid maneuver, after the control input was released; one system in the test surprisingly incorporated a control logic that actively returned it to the point at which the control input was released. Similarly, higher end systems actively seemed to restrict rapid descents to prevent “settling with power” (or vortex ring state), a condition in which the rotor re-ingests its own downwash, while others appeared to provide no provision against this possibly catastrophic condition. Additionally, one system seemed particularly prone to feedback in ground effect (i.e., noticeable as vertical bouncing, during manual landing), while others had less issues or provided landing augmentation. There was also a notable lack of standardization and sometimes proper documentation of some of the autopilot functions, such as home mode. In particular, some systems designated the “home” position as the controller location, at system start up or home mode activation, while other systems designated the lift-off location.

It is highly advisable for operators to familiarize themselves with the particular details of advanced system features, before actively relying on them. Operators should critically assess the size, performance, complexity, and inherent inertia of a system with the intended application and space available in mind (e.g., operational environment). Another important aspect to address is the decision of what level of third-party, commercial-off-the-shelf (COTS; e.g., cameras and sensors, tablet or smartphone, and peripheral controls and displays) integration and support is acceptable, taking into account hardware, software, and the increased complexity of linking requirements. Finally, it is critical for operators to systematically evaluate the potential benefits of a given system, against limitations, constraints, and operational requirements (e.g., laws and regulations; design and business needs; and insurance provisions) before formalizing any purchase agreements. The criteria outlined and presented in this *Consumer Guide* can help readers to understand and evaluate the complexity and capabilities of many consumer sUAS, while providing a consistent method of comparing and evaluating such platforms. However, thorough and independent review of those characteristics most important to the reader should play a central part in the final decision of whether to purchase or use a specific sUAS.

## Future Reviews

The outcomes of this project included system assessment, as presented in the results; development of an example sUAS [Operational Test Plan](#) identifying critical sUAS operational safety considerations; increased ERAU sUAS operational experience; and the design and pursuit of purposeful collaborative sUAS research among students and faculty.

It is anticipated that this *Consumer Guide* will be expanded in subsequent years to provide further guidance and recommendations related to the following:

- Matching specific platforms to intended applications, such as public safety, infrastructure inspection, and precision agriculture
- Inclusion of additional sUAS platforms (4.4 to 55 pounds) and other types of configurations, such as fixed-wing and conventional rotary-wing
- Comparison of specific simulation training and familiarization tools
- Classification including identification of sUAS that incorporate GPS for navigation and positioning and those that do not, as well as those systems featuring the ability to support additional sensors, such as RADAR/SONAR altimeter and optical tracker
- Comparison of payload sensors, such as high definition, multi/hyper-spectral, infrared, radar, and LiDAR
- Detailed examination of automatic functionality, including navigation and path following, geofencing, return to home, and unique aerial filming capabilities
- Human factors analyses of human-machine-interfaces (HMIs) used to interact with, manipulate, and control the systems

The results of this project are also planned to be shared on a dedicated webpage featuring more in-depth information, including dynamic assessment and analyses results and further resources and materials, related to each system examined. In the meanwhile, please feel free follow us on social media:

- Twitter: [@sUASGuide](#)
- LinkedIn ([ERAU Worldwide sUAS Research](#)): <https://www.linkedin.com/groups/8434695>
- Facebook ([ERAU-Worldwide sUAS Research](#)): <https://www.facebook.com/groups/829363647161628/>



*Figure 6. Images from sUAS operational testing event (Bebop 2 and Skycontroller; tethered Typhoon 4K; XPlorer inspection)*

*If you are interested in your sUAS platform being evaluated and included in future iterations of this project or if you would like to learn more about ERAU UAS-related research activities, please contact the Primary Investigator, Dr. Brent Terwilliger ([terwillb@erau.edu](mailto:terwillb@erau.edu)). All gifts received, including financial, equipment, and service donations to Embry-Riddle Aeronautical University, are tax-deductible. Donors will receive a tax receipt following gift processing. You or your organization will also be added to the Acknowledgment section of this guide. Donor of aircraft or financial amounts of \$1,000 or more will also be given an opportunity to name their platform (e.g., "Spirit of Innovation"), which will be used in all subsequent research, marketing, and media coverage.*

## GUIDE DEVELOPMENT TEAM

This project provided an opportunity for ERAU UAS students to work collaboratively with faculty members across campuses, while applying classroom knowledge and building critically needed skills and experience. It also provided researchers with the opportunity to explore specific operational capabilities and support, associated with each system, to gain an improved understanding of critical considerations and safety management strategies to better support safe and appropriate sUAS use.

### Primary Investigator

*Dr. Brent Terwilliger*, Program Chair of the [Master of Science in Unmanned Systems](#) (ERAU-W; oversight, research design, planning, and testing; [terwillb@erau.edu](mailto:terwillb@erau.edu))

### Unmanned Flight Operations/COA Pilot-in-Command

*David Thirtyacre*, Unmanned Flight Operations Chair (ERAU-W; oversight, system management, design, planning, and testing; [thirtyad@erau.edu](mailto:thirtyad@erau.edu))

### Supporting Researcher/COA Visual Observer

*Stefan Kleinke*, Program Chair of the [Bachelor of Science in Unmanned Systems Applications \(BSUSA\)](#); ERAU-W; oversight and operational testing; [kleinkes@erau.edu](mailto:kleinkes@erau.edu))

### COA Sponsor and Visual Observer

*Dr. Chris Walach*, Director of Operations in Unmanned Aviation (NIAS)

### Student Team Manager

*Christian Wilder*, [MSUS](#) (ERAU-W; crowdfunding support, planning, system management, test design, and operational testing)

### Test Lead

*James K. Bonner*, [Master of Science in Aeronautics \(MSA-UAS\)](#); ERAU-W; test design)

### Operations Lead

*Cpt. Brett Chereskin*, [MSUS](#) (ERAU-W; ERAU-DB Army ROTC Faculty; planning, test design, and testing)

### Documentation Lead

*Stacy Martorella*, [MSUS](#) (ERAU-W; test design and operational testing)

### External Communications

*Jonathan Westberry*, [MSA](#) (UAS and Aerospace Operations specializations; ERAU-W; test design, operational testing, and outreach)

*Ryan Langlois*, [Bachelor of Science in Aeronautics](#) (BSA)-UAS minor and [MSUS](#) (ERAU-W; crowdfunding support, test design, and outreach)

### sUAS Operational Testing Team

#### Faculty

- *Dr. David Ison*, [College of Aeronautics](#) Research Chair (ERAU-W; oversight; [isond46@erau.edu](mailto:isond46@erau.edu))
- *Scott Burgess*, Program Chair of the and [BS in Aeronautics](#) (ERAU-W; test design; [burgesco@erau.edu](mailto:burgesco@erau.edu))
- *Dr. Joseph Cerreta*, Assistant Professor (ERAU-DB; oversight and operational testing; [Joseph.Cerreta@erau.edu](mailto:Joseph.Cerreta@erau.edu))

#### Students

- *Jacob Aytes*, [Bachelor of Science in Unmanned Aircraft System Science \(BSUASS\)](#); ERAU-DB)
- *Cody Dangler*, [BSUASS](#) (ERAU-DB)
- *Nicholas Kannard*, [BSUASS](#) (ERAU-DB)
- *Jordan Lamar*, [BSUASS](#) (ERAU-DB)
- *Thomas Ludwick*, [BSUASS](#) (ERAU-DB)
- *K'Andrew France-Beckford*, [BSUASS](#) (ERAU-DB)

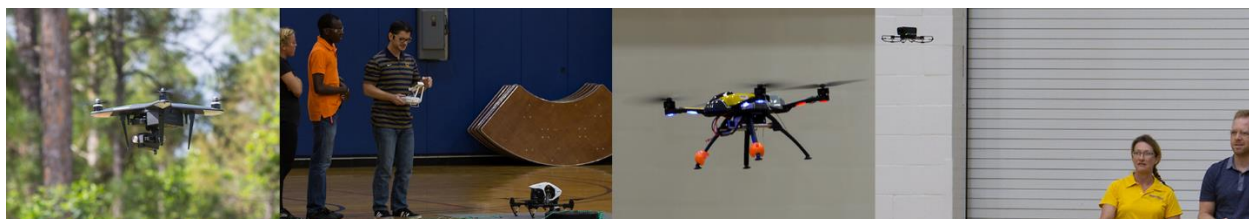


Figure 7. Images from sUAS operational testing event (XPlorer in flight; Inspire 1 pre-flight; Form500 in flight; Cicada in flight)



## Student Research Team

The following ERAU students provided assistance in the design and development of the research; capture, analysis, and presentation of data; and overall support of the project:

- *Matt Pignataro*, [MSUS](#) (ERAU-W; test design and data collection)
- *Jill Brown*, [MSUS](#) (ERAU-W; test design and data collection)
- *Nicholas Damron*, [Bachelor of Science in Technical Management](#) (ERAU-W; test design and data collection)
- *Rollin LeMand*, [BSUASS](#); ERAU-DB; crowdfunding support and data collection)
- *Kalina Gonzales*, [BSUASS](#) (ERAU-DB; data collection)
- *John Middleton*, [BSUASS](#) (ERAU-DB; data collection)
- *Mathew Edeker*, [BSUASS](#) (ERAU-DB; data collection)

## Supporting Administration, Faculty, and Staff

The following ERAU representatives provided essential support for the completion of this project and *Consumer Guide*:

- *Dr. Brad Sims*, Chief Academic Officer (ERAU-W)
- *Dr. Ken Witcher*, Dean of the [College of Aeronautics](#) (ERAU-W)
- *Dr. Dan Macchiarella*, Dean, [College of Aviation](#) (ERAU-DB)
- *Daniel McCune*, Associate Vice President for Safety/Risk (ERAU)
- *Dr. Michael Wiggins*, Department Chair of Aeronautical Science (ERAU-DB)
- *Dr. Dennis Vincenzi*, Department Chair of [Undergraduate Studies](#) (ERAU-W)
- *Dr. Ian McAndrew*, Department Chair of Graduate Studies (ERAU-W)
- *Dr. Patrick Ford*, Assistant Professor of Aeronautics (ERAU-W)
- *Dr. John Robbins*, Program Coordinator of the [BS in Unmanned Aircraft System Science](#) (ERAU-DB)
- *Dr. Robert Joslin*, Adjunct Assistant Professor (ERAU-W)
- *James Roddey*, Director of Communications (ERAU)
- *Molly Justice*, Director of Digital Communications, Digital Strategy and Business Intelligence (ERAU)
- *Gayle L. Larson*, College Administrator & Budget Manager, College of Aeronautics (ERAU-W)
- *Shannon Stenberg*, Assoc. College Administrator, College of Aeronautics (ERAU-W)
- *Chrissy Clary*, Executive Director of Digital Strategy and Business Intelligence (ERAU)
- *Trish Kabus*, Creative Director, University Marketing (ERAU)
- *David Massey*, Multimedia Producer, University Marketing (ERAU)
- *Daryl LaBello*, *Multimedia Producer, University Marketing* (ERAU)
- *George Hanns*, Digital Producer/Usability Specialist (ERAU-W)
- *Paulo Jiminez*, Media Producer (ERAU-W)
- *Greg Igel*, Instructional Design and Development (ERAU-W)
- *Stephen Anest*, Instructional Design and Development (ERAU-W)
- *Tim Davis*, Instructional Design and Development (ERAU-W)



*Figure 8. ERAU-W UAS faculty participating in COA testing (Nevada)*

## CONSUMER RESOURCES

Understanding how to select and operate an appropriate sUAS is only the beginning of the process of maintaining safety in the NAS. The materials presented here have been identified to help better understand permissible operations, best safety practices, outlets for seeking guidance, and ERAU UAS educational opportunities.

### Public Education and Community-based Practices

**[Know Before You Fly](#)** – this website, produced by the FAA and industry partners, provides critical insight and description of operator categories ([recreational](#), [public](#), and [business](#) users), as well as operational guidance for safe and responsible use of UAS: <http://knowbeforeyoufly.org>

**[Academy of Model Aeronautics \(AMA\)](#), [National Model Aircraft Safety Code](#)** – this document codifies community safety guidance for operation of model aircraft (UAS):

<https://www.modelaircraft.org/files/105.pdf>

**[AMA, Membership Manual 2015](#)** – this document contains an overview of who the AMA is, their vision, mission, insurance coverage, as well as general safety practices:

<http://www.modelaircraft.org/files/memannual.pdf>

**[Association of Unmanned Vehicle Systems International \(AUVSI\)](#), [Unmanned Aircraft Systems Operations Industry “Code of Conduct”](#)** – this document codifies an industry policy for safe, professional, and respectful operation of UAS:

<http://www.auvsi.org/content/conduct>

### FAA UAS-related Information

**[Unmanned Aircraft System](#)** – this webpage provides links to important FAA UAS guidance, regulations, and news: <https://www.faa.gov/uas/>

**[Model Aircraft Operations](#)** – this webpage provides detailed information related to the permissible operation of model aircraft:

[https://www.faa.gov/uas/model\\_aircraft/](https://www.faa.gov/uas/model_aircraft/)

**[Civil Operations \(Non-Governmental\)](#)** – this webpage provides detailed information relating to commercial (business) use of UAS, including links to applicable operational approval processes:

[https://www.faa.gov/uas/civil\\_operations/](https://www.faa.gov/uas/civil_operations/)

**U.S. Forest Service, [Unmanned Aircraft Systems](#)** – this webpage features the Federal agency’s policy for the use of UAS, including hobby and recreation, on National Forest System Lands and during emergencies (“*If you Fly, We Can’t*”):

<http://www.fs.fed.us/science-technology/fire/unmanned-aircraft-systems>

**National Telecommunications and Information Administration, [Voluntary Best Practices for UAS Privacy, Transparency, and Accountability](#)** – this document identifies best practices associated with the aerial collection of data to encourage conduct that compliments compliance with the law:

[https://www.ntia.doc.gov/files/ntia/publications/voluntary\\_best\\_practices\\_for\\_uas\\_privacy\\_transparency\\_and\\_accountability.pdf](https://www.ntia.doc.gov/files/ntia/publications/voluntary_best_practices_for_uas_privacy_transparency_and_accountability.pdf)

**National Agricultural Aviation Association, [UAV Safety Education Campaign](#)** – this webpage features a safety campaign to raise awareness of concerns and best practices in agricultural aviation:

<http://www.agaviation.org/uavstuffers>

**[Public Operations \(Governmental\)](#)** – this webpage provides detailed information relating to public (Governmental) agency use of UAS, including links to applicable operational approval processes:

[https://www.faa.gov/uas/public\\_operations/](https://www.faa.gov/uas/public_operations/)

**[Advisory Circular \(AC\) 91-57A \(2015\) Model Aircraft Operating Standards](#)** – this updated AC contains information relating to categorizing model aircraft and UAS as “aircraft” in the National Airspace System (NAS), recreational use, operational hazards, and permissible and prohibited operations:

[https://www.faa.gov/documentLibrary/media/Advisory\\_Circular/AC\\_91-57A.pdf](https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_91-57A.pdf)

**Unmanned Aircraft Operations in the National Airspace System** (N JO 7210.889) - this notice contains information and guidance on air traffic policies, as well as planning, coordination, and services associated with the operation of UAS:  
[http://www.faa.gov/documentLibrary/media/Notice/N\\_JO\\_7210.889\\_Unmanned\\_Aircraft\\_Operations\\_in\\_the\\_NAS.pdf](http://www.faa.gov/documentLibrary/media/Notice/N_JO_7210.889_Unmanned_Aircraft_Operations_in_the_NAS.pdf)

## Advocacy Organizations

**AMA – What is the AMA?** - this advocacy organization represents more than 175,000 members in the promotion and safe guarding of model aviation as a recreational pursuit through interaction with all levels of government:  
<http://www.modelaircraft.org/aboutama/whatisama.aspx>

**Aircraft Owners and Pilots Association (AOPA) – Unmanned Aircraft Systems** – this General Aviation advocacy and service organization represents its membership to all levels of government, provides legal services, advice, and assistance, as well as collaborating with other aviation stakeholders to ensure continued safety, accessibility, and resources:  
<http://www.aopa.org/News-and-Video/Aircraft-Types/UAVs>

## Other UAS Tools and Resources

**FlightService, 1800wxbrief**– this website provides information to help UAS operators identify, review, and visualize weather and subsequent weather-related hazards that may compromise safety:  
<https://www.1800wxbrief.com/Website/#/>

**Know Before You Fly, U.S. Air Space Map** – this webpage provides an interactive map (powered by [AIRMAP](#)), depicting radius, outlines, and contact details for areas where UAS operations are prohibited or must be coordinated with local FAA air traffic control authorities:  
<http://knowbeforeyoufly.org/air-space-map/>

**DIY-drones Discussion Forum** – this interactive and shared online community contains discussions posts relating to user’s experiences with specific platforms, operations, or developments:  
<http://diydrones.com/forum>

**sUAS Registration Service** – this page contains details regarding registration of sUAS (.55-55 lbs), including access the online registration portal; required for all operators 13 years and older intending to operate a sUAS in the NAS:  
<https://registermyuas.faa.gov>

**AUVSI – Who is AUVSI?** – this advocacy organization represents more than 7,500 members, from across government, industry, and academia, and is focused on supporting the development and promotion of unmanned systems:  
<http://www.auvsi.org/home/learnmore>

**National Business Aviation Association (NBAA) Aircraft Operations – Unmanned Aircraft Systems** – this organization represents more than 10,000 companies and recognizes the economic potential of UAS, as well as the need for equivalent standards, certification, airworthiness, and safety, as manned aviation: <https://www.nbaa.org/ops/uas/>

**DRONELife.com, Buy a Drone** – this online database, with more than 150 entries, serves as an interactive tool to search for consumer and commercial sUAS platforms meeting specific user defined criteria, such as price range, camera, applications, type, battery life, experience level, and manufacturer:  
<http://dronelife.com/cms/product-filter>

**specout, Compare Drones**- this online database, with more than 500 entries, serves as an interactive tool to search and compare reported metrics for consumer sUAS platforms meeting specific user defined criteria, such as price, expert reviewed, applications, built-in-camera and specifications, manufacturer, model, performance, control system, wingspan, weight, and compatibility:  
<http://drones.specout.com>

**ERAU UAS Programs and Information****ERAU-Worldwide Campus**

**Office of Professional Education-Worldwide, Professional Program in Small Unmanned Aircraft Systems (sUAS)** - non-degree program featuring three (four-week, online) courses covering history and application, design and configuration, and operations and regulations. Participants explore today's most innovative and exciting sUAS uses, learn about operating sUAS safely and legally, and connect with resources to remain current.

**Note:** *This non-degree program does not substitute for a license, degree, certification or required professional credential. A certificate of completion is issued upon successful completion of all three courses.*

**Bachelor of Science in Unmanned Systems Applications (BSUSA)** – online degree program designed to provide broader and more affordable access to an undergraduate-level education in a topic under-represented in global educational institutions, the application of unmanned system technology: <http://worldwide.erau.edu/degrees-programs/programs/bachelors/unmanned-systems-applications/index.html>

**Bachelor of Science in Aeronautics (BSA)-UAS Minor** – degree program (classroom and online) featuring an 18-credit minor course of study to improve awareness of system capabilities, unique robotic features, sensor selection and application, and role in modern operations: <http://worldwide.erau.edu/degrees-programs/programs/bachelors/aeronautics/index.html>

**Master of Science in Unmanned Systems (MSUS)** – online advanced degree designed to produce graduates qualified to enter or enhance their applicability towards the application, development, management, policy-making, and support of unmanned systems:

<http://worldwide.erau.edu/degrees-programs/programs/masters/unmanned-systems/index.html>

**Master of Science in Aeronautics (MSA)** - advanced degree program (classroom and online) featuring a 12-credit graduate specialization (four courses) in UAS emphasizing need for a comprehensive understanding of UAS topics, challenges, and application: <http://worldwide.erau.edu/degrees-programs/programs/masters/aeronautics/index.html>

**ERAU-Worldwide Unmanned Systems Related Career Opportunities: 2016** – this report contains an overview of the types of fields and positions associated with unmanned systems, including UAS, as well as current pay-scales and growth locations across the U.S.:

<http://worldwide.erau.edu/Assets/worldwide/forms/ERAU-Unmanned-System-Graduates-Potential-Job-Opportunities-2016a.pdf>



Figure 9. Images from ERAU-Worldwide (Aerial Robotics Virtual Lab; faculty and students examining UAS simulation tool)



**ERAU-Daytona Beach (Residential) Campus**

**Office of Professional Education-Daytona Beach, [Unmanned Aircraft Systems \(UAS\) Seminar & Industry Certificate](#)** - This three-day Embry-Riddle Unmanned Aircraft Systems (UAS) course is designed to identify the key concepts, attributes, and challenges of UAS operations. Participants will receive 2.4 continuing education units (CEUs) for successful completion of this course through ERAU.

**Note:** *This non-degree seminar does not substitute for a license, degree, certification or required professional credential. A Small UAS Safety Awareness certificate is issued upon successful completion of the course.*

**[Bachelor of Science in Unmanned Aircraft System Science \(BSUASS\)](#)** – residential undergraduate degree program designed to give graduates the expertise they need for employment as operators, observers, sensor operators, and operations administrators of unmanned aircraft systems: <http://daytonabeach.erau.edu/degrees/bachelor/unmanned-aircraft-systems-science/>

**[Unmanned Aircraft Systems Applications Minor](#)** - 20-credit minor course of study, featuring classroom and laboratory coursework in private pilot operations, UAS, operations and cross-country data entry, mission planning, crew resource management, unmanned sensing systems, and payload application: <http://catalog.erau.edu/daytona-beach/minors/unmanned-aircraft-systems-science/>

**[Master of Science in Unmanned and Autonomous Systems Engineering \(MSUASE\)](#)** – an advanced degree to prepare students to work in an industry developing systems that operate along a spectrum of autonomy, from unmanned aircraft and autonomous cars to robotic surface water and underwater vessels, spacecraft and industrial robots: <http://daytonabeach.erau.edu/degrees/master/unmanned-autonomous-systems-engineering/index.html>



Figure 10. ERAU-Daytona Beach campus students using medium altitude long endurance UAS simulators

**ERAU-Prescott (Residential) Campus**

**[Bachelor of Science in Unmanned Aircraft Systems \(BSUAS\)](#)** – residential undergraduate degree program designed provide the necessary expertise for graduates to obtain employment as pilots/operators, observers, sensor operators, and/or operations administrators of UAS: <http://prescott.erau.edu/degrees/bachelor/unmanned-aircraft-systems/index.html>

**[Unmanned Aircraft Systems Minor](#)** – 21-23-credit minor course of study, featuring coursework in UAS operations, cross-country data entry, global UAS regulations, unmanned sensing systems, and UAS flight simulation: <http://catalog.erau.edu/prescott/minors/unmanned-aircraft-systems/>





Figure 11. ERAU-Prescott campus students configuring a multirotor sUAS

### **ERAU UAS Research**

[ASSURE at ERAU](http://assureuas.erau.edu/) – this webpage features descriptions of ongoing UAS research, performed with academic and industry partners, in support of the FAA UAS Center of Excellence ([ASSURE](http://assureuas.erau.edu/)): <http://assureuas.erau.edu/>

[Research @ Embry-Riddle](http://research.erau.edu/) – this webpage features news, overviews, and links to research projects being conducted at ERAU: <http://research.erau.edu/>

[ERAU Scholarly Commons](http://commons.erau.edu/) - this open-access digital library of intellectual output is used to collect, preserve, and disseminate the University community's research and provide a digital showcase for campus publications, archival materials, library special collections, and other University-related creative works not published elsewhere: <http://commons.erau.edu/>

[Next-Generation ERAU Advanced Research \(NEAR\) Lab](https://daytonabeach.erau.edu/about/labs/next-generation-erau-advanced-research/index.html) – this for-hire research facility located on the ERAU-Daytona Beach campus carries out applied research with avionics companies, aircraft manufacturers, communications providers, commercial airlines, and governmental agencies such as NASA and the FAA: <https://daytonabeach.erau.edu/about/labs/next-generation-erau-advanced-research/index.html>

[Eagle Flight Research Center](https://daytonabeach.erau.edu/about/labs/eagle-flight-research/index.html) - serves as ERAU's Aerospace R&D facility and features an experienced collection of professors, staff, consulting FAA-Designated Engineering Representatives (DERs), pilots, and technicians experienced with experimental aircraft, certification, instrumentation, and data gathering and analysis: <https://daytonabeach.erau.edu/about/labs/eagle-flight-research/index.html>



Figure 12. ERAU UAS research (GALE UAS; students and faculty examining multirotor sUAS; UAS club member prepares sUAS)

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