Urban Air Mobility (UAM)

INDUSTRY STUDY

WIND™

STUDY OVERVIEW

Objectives

Wind River, a global leader in delivering software for the intelligent edge, commissioned Endeavor Business Media to conduct a web-based survey to learn about strategic issues, use cases, and related trends in the Urban Air Mobility (UAM) market. In addition, the study aimed to better define some of the specific cybersecurity, safety, and subsystem development issues facing companies that are either currently conducting and/or planning Unmanned Aircraft Systems (UAS) programs.

The survey was conducted between mid-June and early-July 2019, and included respondents randomly recruited from a select, pre-qualified list that was part of Endeavor Business Media's ***Military & Aerospace Electronics*** magazine database. The types of organizations represented in the survey results included:

- Prime contractors
- Subcontractors and system integrators
- Manufacturers of finished Electronic/Software products used by the UAM industry and of electronic sub-assemblies and major system components
- Department of Defense (DOD) agencies
- Government and private industry R&D organizations, and
- Non-DOD agencies such as NASA, FAA, and other government aeronautics agencies and facilities (although non-DOD intelligence agencies and facilities were excluded from the sample).

Methodology

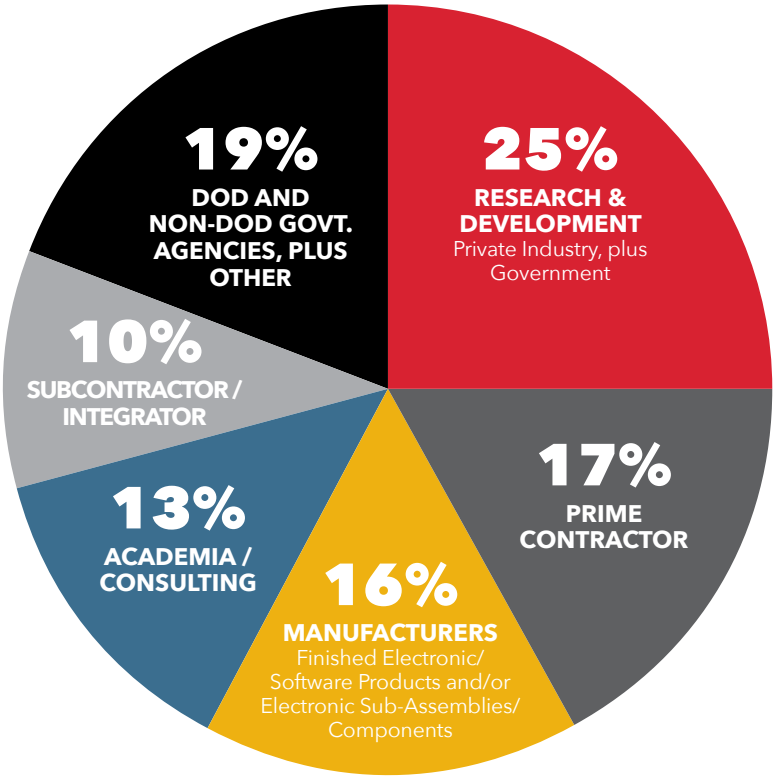
Decision-makers and influencers from several different Engineering, Engineering Management, Executive Management, Operations, and Sales related job titles & functions were invited to participate in the study. Some of the types of UAS systems that they work with include integrated circuits, I/O boards, embedded computers, software, communications, design & development tools, test & measurement equipment, power electronics, and other UAS components.

RESPONDENT PROFILE

The survey sample included 125 respondents, with precision estimated at +/- 8.8 at 95% confidence. Following an introductory section of the survey where Urban Air Mobility (UAM) and related Unmanned Aircraft Systems (UAS) were defined, the respondents were asked several profile questions to further qualify and characterize those participating in the study:

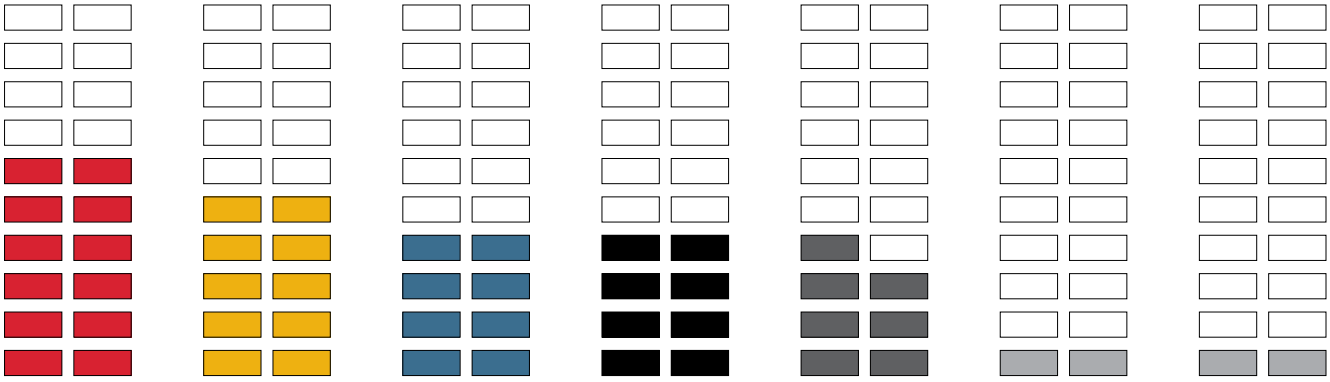
Type of Organization

A good mix of organizations were represented in the study, with respondents being from over 10 different organization types.



Area of Involvement in Autonomous Vehicle Industry

Decision makers were adequately represented in the study, with 38% of respondents involved in 'Setting overall vision and strategy' and 11% responsible for 'Approving budgets'. However, this graph shows that the most frequently mentioned areas of UAM involvement were R&D, project implementation, and 'other decision influencing functions' related areas:



62% Researching and evaluating solutions

47% Defining requirements

43% Implementing and managing solutions

42% Making final recommendations regarding solutions

38% Setting overall vision and strategy

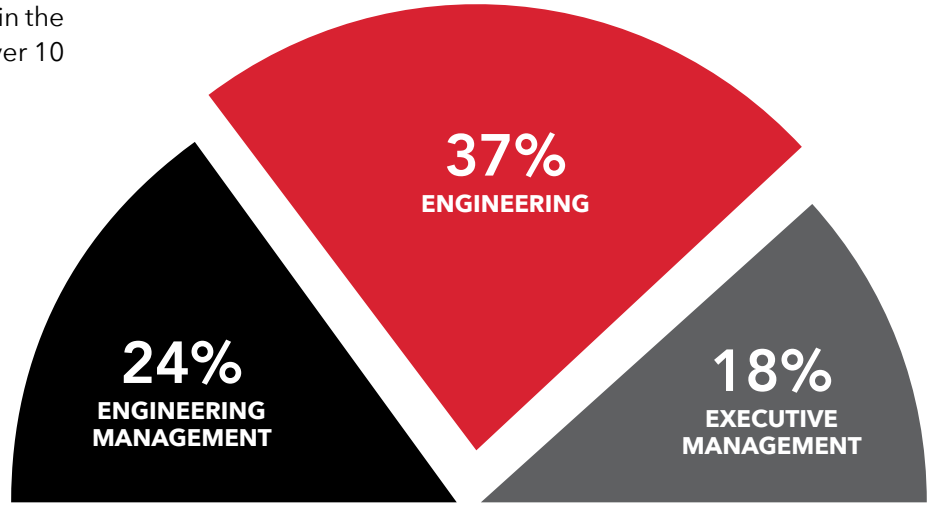
11% Approving budgets

10% Other

RESPONDENT PROFILE

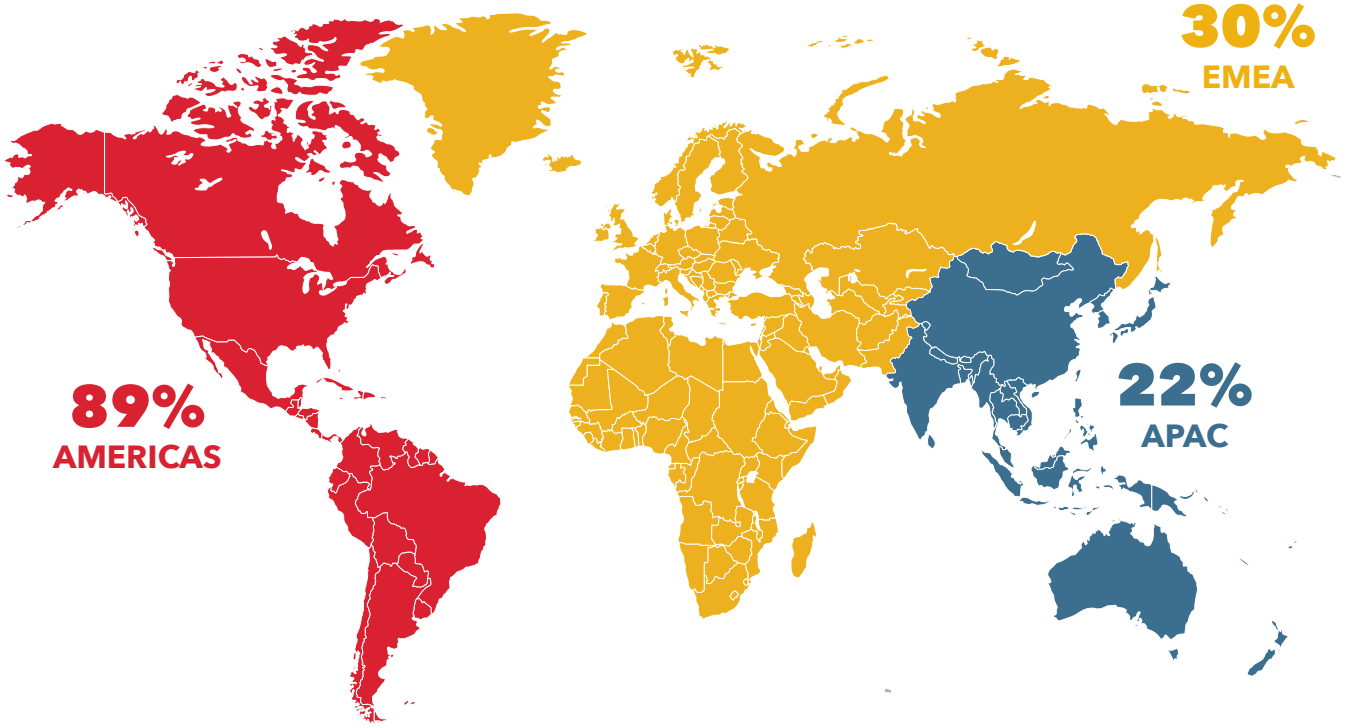
Job Function

A good mix of titles were represented in the study, with respondents being from over 10 different organization types.



Operating Locations

Respondents' companies predominantly operated in the Americas (89%), as shown in the figure below. However, companies operating in EMEA and/or APAC were well-represented, with 30% and 22% of respondents (respectively) indicating that they operated in these world areas.



EXECUTIVE SUMMARY

Key findings from this 2019 Urban Air Mobility Study included:

1 **Governmental/institutional based use cases are expected to lead in the UAM market, with transportation and data collection services likely to be the initial private sector-based applications.**

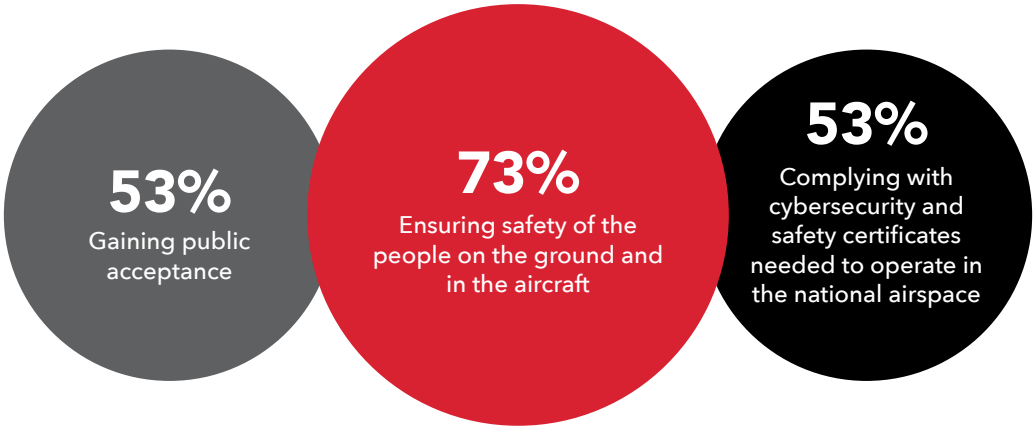
- 'Surveillance, ground traffic, and law enforcement operations' and 'Emergency medical evacuations, rescue operations, and humanitarian missions' are currently the most mentioned UAM use cases.
- Respondents anticipate 'monetizing transportation services' and 'monetizing data collection services' to be the most successful business models, indicating these are most likely use cases when the private sector enters the UAM market.

2 **UAM is currently still in the early stages of development, although significant UAM programs are expected to be part of many responding organizations' business strategies in the next 1 to 3 years.**

- Only 11% of respondents' organizations are currently at either the "Prototype/Fielding" or "Deployment" stages of the development cycle for their most strategically important UAM programs.
- However, this situation is changing: almost half of the survey respondents (46%) said that UAM will be 'a significant part of (their) organizations' business strategy in the next 1 to 3 years'.

3 **'Ensuring safety', 'Gaining public acceptance', and 'Cybersecurity/safety certification compliance' are the key challenges facing UAM, according to survey respondents.**

- The key challenges identified by respondents are



- Additional UAM challenges and/or opportunities identified via open-ended question include: (i) sub-system development (e.g. AI; multi-use platforms; system reliability); (ii) regulations and standards for the UAM industry (e.g. operating agreements; command and control structure; integration with conventional air traffic); and (iii) addressing key business issues in the UAM market (e.g. competition with existing services; closing the profitability loop; liability of casualty events).

EXECUTIVE SUMMARY

4

Cybersecurity and safety standard compliance are considered key, although stronger consensus around specific standards within the UAM industry is still needed.

- While the most-mentioned cybersecurity standard is 'ISO 27000 series', only 47% mentioned it; in addition, respondents still consider 'certification/approval requirements' to be the most significant obstacle to organizational compliance (43% indicated).
- Survey respondents feel that manned and unmanned urban aircraft should follow similar/same safety procedures and certifications (69% agreed), although some feel the standards applicable toward unmanned aircraft should be more stringent. There is still limited consensus on what specific safety standards are applicable, with 40% or fewer respondents mentioning each of the primary two standards: 'FAA Part 107' (40% mentioned) and 'FAA Part 23/EASA CS-23' (37%).
- However, there is relatively strong consensus regarding COTS components, with 80% of respondents saying they are likely to use these. There is also a relatively strong preference (66% favored) that safety and security technology be 'built into the software and/or hardware platforms.'

69%
AGREED
manned and unmanned urban aircraft should follow similar/same safety procedures and certifications

80%
would likely use COTS components

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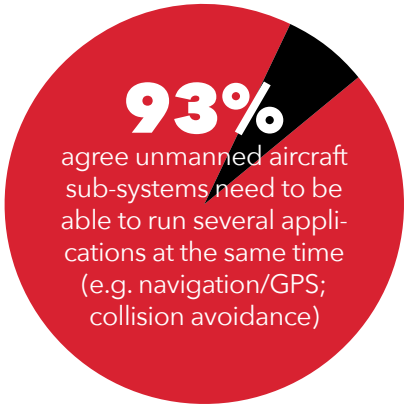
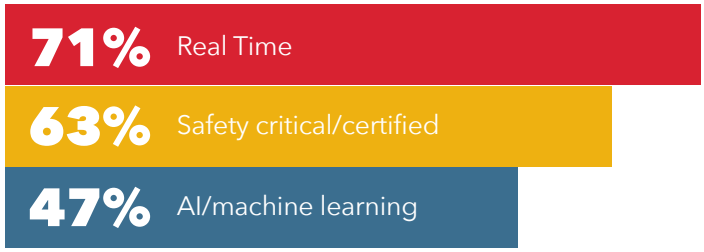
UAS sub-systems play a key role in making the UAM market viable, with respondent preferences for systems' ability to run several applications at once and the ability to migrate existing applications to their current and/or next designs.



Key applications to consolidate or add include



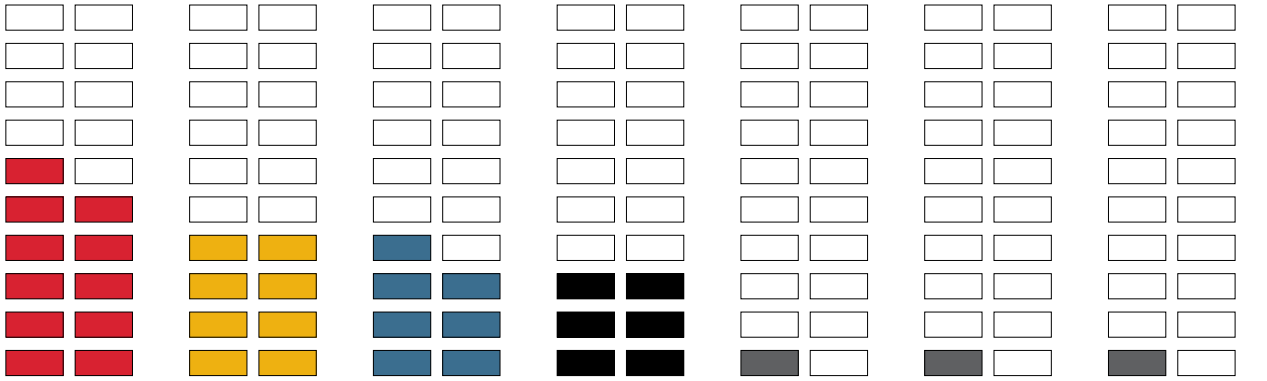
- Most respondents (83%) considered the ability to 'migrate existing applications to (their) current/next design' as at least 'somewhat important.'
- The most preferred operating system (OS) is 'some form of Linux' (61% mentioned one of 7+ choices), followed by Google® Android® (36%) and Microsoft® Windows® (33%). Hardware/processor preferences include Intel Xeon, Core i5/i7 and Atom (62% mentioned) and Arm Cortex A5x, A7x, and R5x (40%).

Strategic Issues Related to the UAM Market

1 Strategically Important Use Cases and Types of Operations

Urban Air Mobility Study respondents thought that the most strategically important use cases and/or types of UAM operations were 'Surveillance, ground traffic and law enforcement operations' (55% mentioned) and 'Emergency medical evacuations, rescue operations, and humanitarian missions' (40% indicated).

Additional types of UAM operations of interest



55%
Surveillance, ground traffic and law enforcement operations

40%
Emergency medical evacuations, rescue operations, and humanitarian missions

35%
Air cargo

30%
On-demand air taxi or regularly scheduled 'air metro' operations

5 Mentions
Military and defense applications, including Space & Defense systems

5 Mentions
Resource monitoring, crop monitoring, agricultural research, and wildlife/fish management

Other
Firefighting and police applications, including assistance in catastrophes
Oil & gas operations
Remote repair & maintenance
Filming institutional videos

2 Anticipated Most Successful Business Models for UAM

Survey respondents expected two specific business models to be the most successful ones for the UAM market (with each being mentioned by just under one-third of respondents as the 'most successful' model):

- 'Monetizing transportation services' and
- 'Monetizing data collection services (e.g. weather, air quality, surveillance, and related)'.

'Monetizing equipment (i.e. non-shared individual or corporate ownership)' and 'Monetizing the web and mobile apps that aggregate data reports' were the third and fourth most successful models, respectively.

3 Stage in Development Cycle for Most Strategically Important UAM Applications

Figure 1 shows where the survey respondents are at within the development cycle for their UAM applications; if they have multiple programs underway at different stages, they provided a response related to their one program with the most strategic importance to their organization.

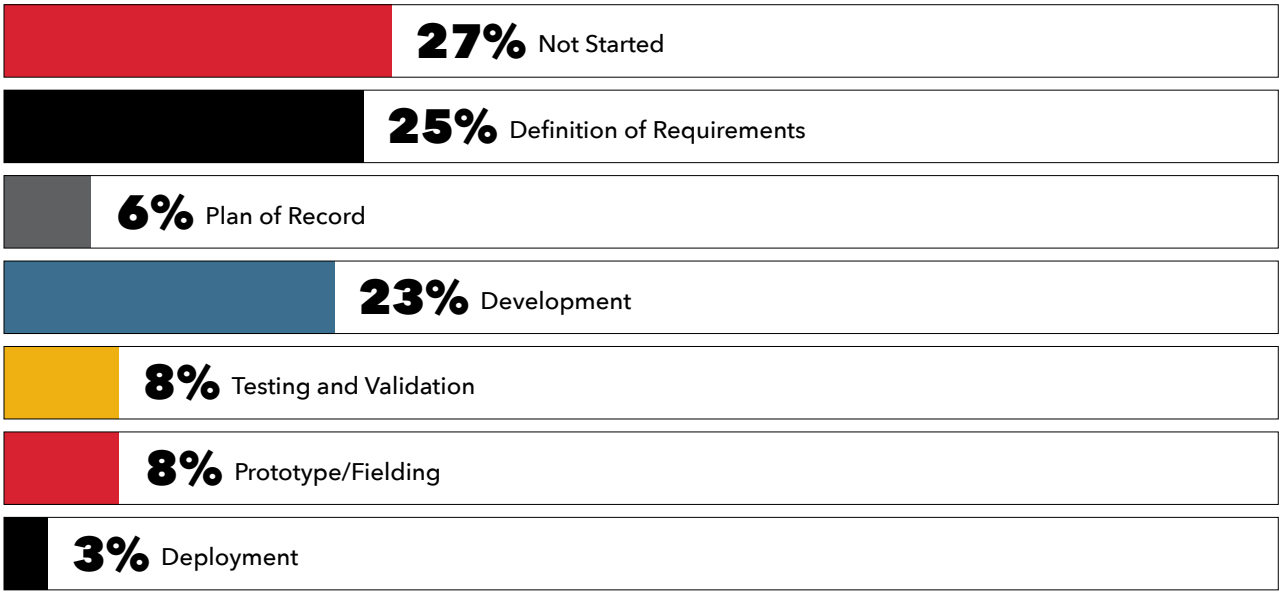


FIGURE 1

About three-fourths of respondents fall into one of the following 3 development cycle stages:

- **Not Started** – over a quarter (27%) of respondents are at this stage of the cycle, and **figure 2** shows when this group anticipates beginning the next stage, 'Definition of Requirements', with 44% of this segment saying 'I don't know' re: timing, and another 44% planning to define requirements within the next 3 years (including 15% of this 'Not Started' segment that plans to begin requirements definition 'Within the next year').
- **Definition of Requirements** – a quarter (25%) of respondents are currently at the requirements definition stage.
- **Development** – just under a quarter (23%) of respondents have a program now under development.

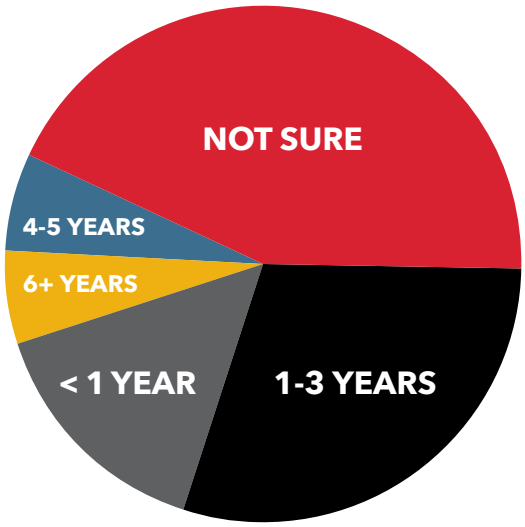


FIGURE 2

3

The UAM industry is still in its relatively early stages. Approximately 42% of respondents were at the 'Development' stage or later for their most strategically important program, and only 11% of respondents were currently in either the 'Prototype/Fielding' or 'Deployment' stage.

Also, the percentage of 'Not Started' stage respondents that either 'don't know' their timing of Definition of Requirements or anticipate it to be 4+ years away is over half (56%) of this 'Not Started' segment, and they represent 15% of the overall respondent base.

When respondents were asked whether UAM will be 'a significant part of (their) organization's business strategy in the next 1 to 3 years', approximately 46% agreed (although only 5% strongly agreed); see **Figure 3** for additional response detail.

An important factor contributing to these findings re: Development Cycle and UAM's role as a 'significant part of (their) organization's business strategy in the next 1 to 3 years' are the 'Key Challenges' that respondents identified (see the next section).

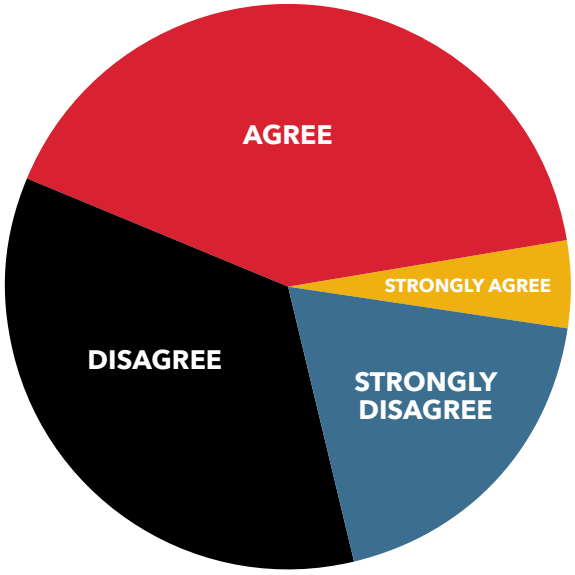


FIGURE 3

4

Key Challenges in Creating Unmanned Aircraft Systems (UAS) for UAM

Respondents were asked to identify the key challenges in creating unmanned aircraft systems (UAS) for the Urban Air Mobility (UAM) market. **Figure 4** shows the key results, with three challenges being the most compelling ones for respondents:

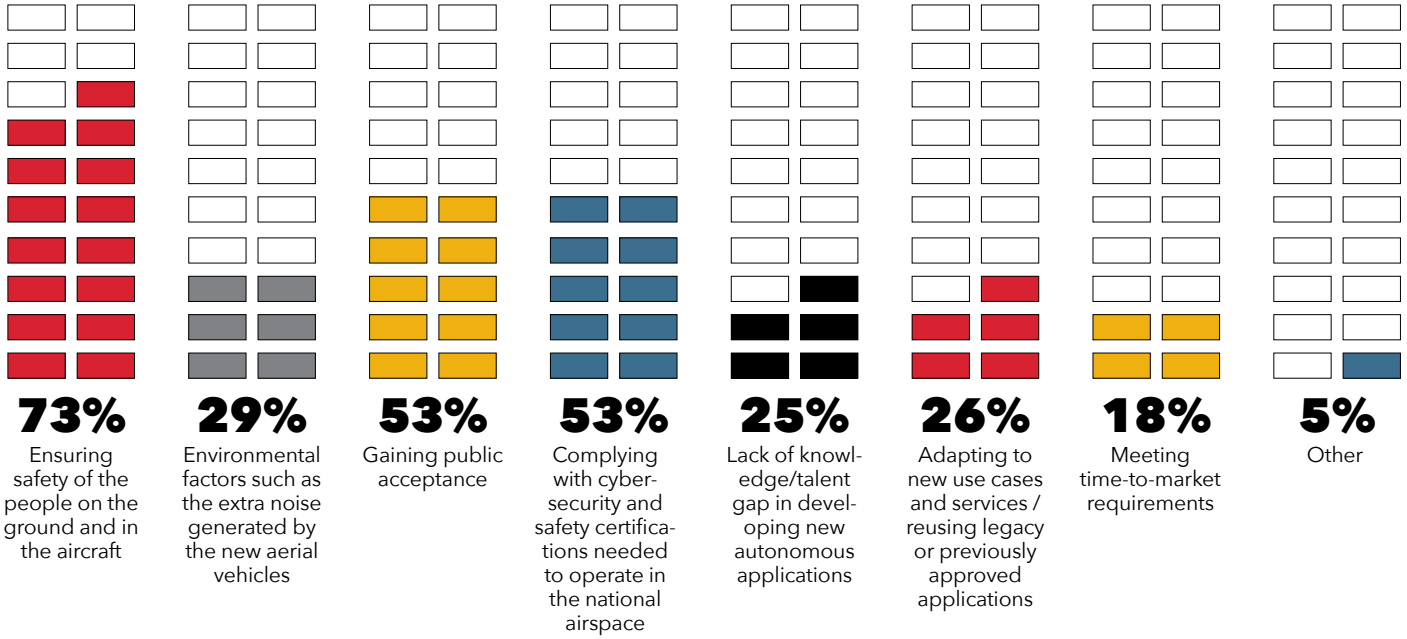
- Ensuring safety of the people on the ground and in the aircraft (73% selected)
- Gaining public acceptance (53%)
- Complying with cybersecurity and safety certifications needed to operate in the national airspace (53%)

Some additional comments were shared by a few of the respondents:

- "The field is being rushed into when it shouldn't be due to possible involvement of unaware people the devices may pass over."
- "Lack of scientific use case publicity around success stories; NASA auto lander and auto docking would be great (use cases)."
- "Control and guidance system development and integration" is important.
- "Bandwidth and network capacity in high density environments" are key considerations.

Key Challenges in Creating UAS for UAM Markets

FIGURE 4



5 Other Trends and/or Strategic Issue Areas that Need to be Addressed by the UAM Industry to Better Encourage Safe & Secure UAS Development

Most of the 'Other Trends and/or Strategic Issue Areas' mentioned by respondents (n = 52), which was asked as a wrap-up question in the initial 'Strategic Issues' section of the survey, grouped into a few key categories: (a) Sub-Systems and Other Technical Issues (n=15); (b) Regulatory and/or Standards Issues (n=14); (c) Use Cases and Business Related Issues (n=9); (d) Safety and/or Security Related Issues (n=8); and (e) Other Issues (n=6).

Key findings from the top 4 issue areas (including representative verbatim comments) are summarized below; they provide a glimpse into additional UAM challenges and/or opportunity areas:

- **Sub-Systems and Other Technical Issues** – one of the two top areas where survey respondents identified key issues. Additional sub-system and technical issue areas that they see as critical for the success of the UAM market included:
  - "AI (i.e. artificial intelligence) development"
  - "Multi-use platforms to perform more than one use case"
  - "Deconfliction with other UAM platforms, collision avoidance, etc." with another saying "Crash avoidance, endurance and payload"
  - "Certifying the analytics at the edge, significantly reducing SWaP, certifying highly converged/consolidated systems"
  - "Protection from electronic interference"

5

- "Reliable navigation, reliable collision avoidance" with another saying "Reliability of engine systems and AI"
- "Implementation of an effective unit system failure/emergency backup hardware implementation plus recovery processes and procedures"
- "Developing newer energy storage solutions to improve range and drive better returns on larger payloads" with another indicating that "Carbon footprint" needs to be considered
- "Recovery Options, such as device failure options and/or defined travel routes to ensure airspace above people is protected from device failures and personal property loss in the event of a failure"
- Systems that are "safe, user-friendly, environmentally-friendly, and (utilize) superior technology"
- "The operational platforms are MORE than 'just drones', in range, performance and air/land/sea transitions with the same UAM".
- One "Safety and/or Security" respondent shared one technical comment in his response: "Engine types vis a vis pollution"

Regulatory and/or Standards Issues – another top area where survey respondents identified critical-to-success issues. Additional Regulatory and Standards issue areas that they see as needing to be addressed included:

- "Protocols, operating agreements, command and control structure, bandwidth and network capacity"
- "Establishing industry standards for airworthiness"
- "Regulation of how this type of aircraft will not interfere with normal manned aircraft airport operations" with another saying "Integration with conventional air traffic"
- "Interoperability protocol"
- "Regulations (for) and expansion of roof top helipads … (also) adapting of electronic(s) for navigation on cities"
- "Government partnership"
- One respondent commented: "Regulatory issues are overplayed. Much higher safety requirements than self-driving GVs."
- Another commented: "the industry is NOT addressing local governments … if they continue to ignore the villages, fear of these products will continue to grow"
- Additional concern areas mentioned included: "police cooperation", "terrain for UAM rules", "FAA and public acceptance of employing UAM in the National Airspace" and "certification requirements".

IMPORTANT SUB-SYSTEMS ISSUES:

Artificial intelligence Development

Multi-Use Platforms to Perform More than One Use Case

Reliable Navigation, Collision Avoidance, and Engine Systems

IMPORTANT REGULATORY & STANDARDS ISSUES:

Protocols

Operating Agreements

Command and Control Structure

Network Capacity

Industry Standards for Airworthiness

DETAILED SURVEY FINDINGS

5

Use Case and Business-Related Issues – comments in this category were quite varied, although all related to business/use cases or to business-related (including marketing) issues that affect the UAM market:

- "Competition with existing services"
- "Developing business case that closes profitability loop"
- "Price model and marketing"
- "Cost consideration. Affordable to all."
- "Gaining access to VC monies by demonstrating the technology meets the needs of the market."
- "This transportation modal should first operate on specific niches such as rescue vehicles and services operating under specific rules to acquire public confidence. Only after this phase it should try to expand into new fields."
- "Liability of casualty events, (including) proof of correct autonomous actions taken by vehicle to avoid casualties. Validation of operating conditions of vehicles when they are using AI and DL."
- "Distribution of the personally owned air car will change the face of the 'best place to live' market … to a much greater factor than the personally owned car did -- which at the time was little noted but staggering in its scope."

Safety and/or Security Related Issues – some respondents voiced general comments related to Safety and/or Security; those verbatims with more specific comments and recommendations are shared below:

- "Safety is high priority. Also secure communication channels. Constant surveillance."
- "Too dangerous in heavily populated areas; malfunction and/or misuse; hacking"
- "Avoiding traffic jamming" with another saying "Avoiding air conflict with manned aviation"
- "Cybersecurity threats pertaining to hacking"
- "Secure comm & pnt (nextnav)"
- Note: directly following this last "Strategic Issues" question, respondents answered detailed questions specifically related to 'Cybersecurity and Safety Compliance Issues' (see the next section below).

IMPORTANT BUSINESS-RELATED ISSUES:

Competition with Existing Services

Price Model and Marketing

Liability of Casualty Events

IMPORTANT SAFETY AND SECURITY ISSUES:

Secure Communication Channels

Operating Agreements

Heavy Traffic and Conflict with Manned Aviation

Cybersecurity Threats

Cybersecurity and Safety Compliance Issues Related to UAM Initiatives

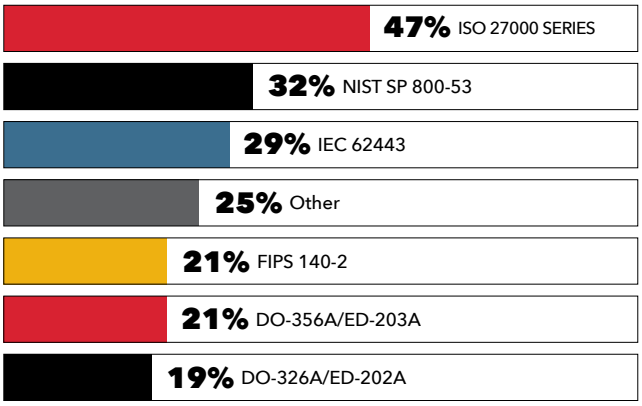
6 Cybersecurity Standards and Compliance

The most frequent cybersecurity standard that respondents said unmanned aircraft systems (UAS) programs would need to comply with was the ISO 27000 Series (47% mentioned), followed next by NIST SP 800-53 (32%) and IEC 62443 (29%). **Figure 5** provides more detailed response data, with approximately 15% of respondents indicating 'don't know' to this question (as part of 'Other' responses).

When asked about the 'significant obstacles to your organization in adopting and complying with cybersecurity requirements', the most frequent responses (shown in **Figure 6**) were:

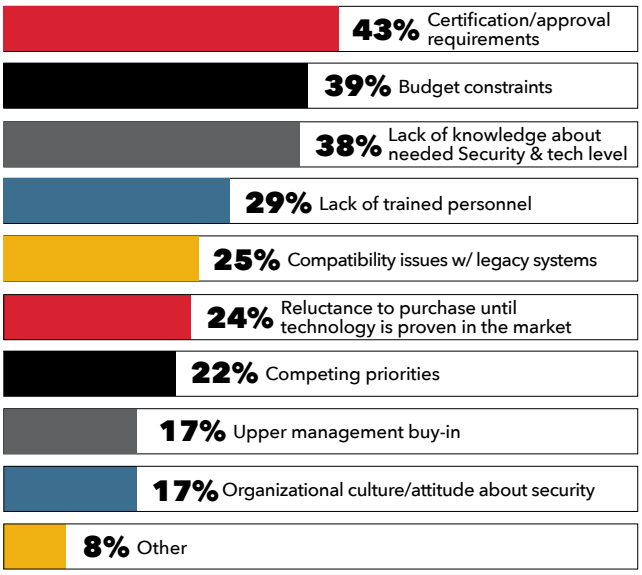
- Certification / approval requirements (43% indicated)
- Budget constraints (39%)
- Lack of knowledge about the needed level of security and tech (38%)

Obstacles such as 'Lack of trained personnel' (29%), 'Compatibility with legacy systems' (25%), 'Reluctance to purchase until technology is proven in the market' (24%), and 'Competing priorities' (22%) were also notable as they were cited by roughly one-in-four respondents.



n = 99

FIGURE 5



n = 99

FIGURE 6

7 Safety Standards and Compliance

Over two-thirds of respondents either 'Agree' (51%) or 'Strongly Agree' (18%) that "both manned and unmanned urban aircraft should follow similar, if not the same, safety procedures and certifications (see **Figure 7**). Only 12% of respondents 'Strongly Disagree' with this statement.

Key reasons for their responses were explained in a follow-up open-ended question (n = 59); a summary of comments from each segment, plus representative verbatims, are provided below. Overall, respondents felt that safety procedures and certifications should be 'at least' similar/same as for manned aircraft, with some (both from the 'Agree' and 'Disagree' segments) advocating more stringent procedures for unmanned aircraft. (Note: the response categories below correspond to those provided in **Figure 7** and summarized above.)

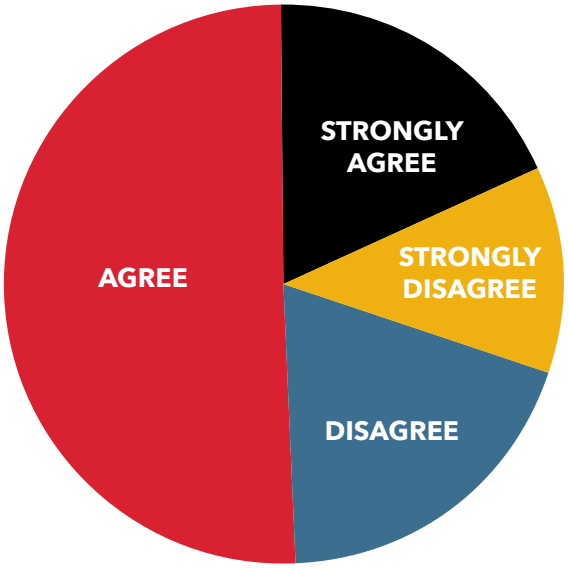


FIGURE 7

"Strongly Agree" Segment (n=12 for open-ended responses)

These respondents were highly focused on safety issues and advocated the same procedures required for UAS as for manned vehicles. Representative comments included:

- "Manned and Unmanned Vehicles have to be on the same page to (ensure) safety and security."
- "There should not be a difference between manned and unmanned. Each can pose challenges that need to be met with security protections."
- Same procedures "because they both will be utilizing airspace and an air traffic management system."
- Using the same procedures "lowers nonconformity, minimizes gaps between manned and unmanned."
- UAM requires similar standards because "urban areas are mostly densely populated areas."
- "The nation and general public must know that UAS are safe and airworthy with positive C2."

"Agree" Segment (n=26)

This respondent segment echoed similar sentiments re: safety as the 'Strongly Agree' segment, with some respondents advocating even more stringent procedures for unmanned vehicles. Public acceptance and buy-in continued to be a theme discussed by this respondent group.

- "Safety is paramount to public acceptance."
- "The only way to achieve user buy-in is to use familiar protocols with proven use cases, then build on it."
- "Anything flying overhead should be taken seriously. The public has not much faith in the aircraft industry, let alone the "self-flying" equipment."
- "Unmanned devices need not only comply with existing, defined ones, but should also include additional ones on top of those (procedures), since the devices are remote and human pilot interaction and/or decision making is not present or may be cut off in an event."

7

- "The security should be more advanced for unmanned aircraft due to the lack of personnel on board."
- "Both manned and unmanned aircraft will need to comply with cyber security mandates in order to secure communications and prevent (an) adversary from controlling the aircraft remotely."
- "This (i.e. similar/same procedures) will be certainly a requirement from FAA/EASA, so there is no point to create, expect, or lobby for different/additional requirements."
- "Both systems are under the responsibility of a person, who must finally assume any error."
- "They both operate in the same airspace. They should behave the same otherwise we will have confusion."
- "Both should operate under the same guidelines to (simplify) compliance."
- "The ramifications of failure to comply are the same for manned and unmanned aircraft."

"Disagree" Segment (n=14)

Mostly, this group of respondents highlighted the additional challenges associated with UAM applications and tended to advocate even more stringent procedures and operating limitations for unmanned vehicles.

- "The engineering for the safety of unmanned AC (i.e. aircraft) is wildly different than the engineering for manned AC."
- "It would be prudent to implement more stringent safety and security requirements for UV's (due) to the expected volume and air space vehicle requirements, differences in altitude (and) space mandates, types of payload restrictions and permissions, proximity to target destinations, and the like. In addition, there would be obvious area restriction requirements to be factored into any implementation. Politics and insurance policy (issues) will be (other) major challenges."
- "UAM - until proven otherwise - will have to operate in a more 'controlled' and predictable manner."
- "Manned (aircraft) reaction can be changed upon the situation and unmanned has to be compute for any case study."
- UAM involves a different environment with "lower flight paths, shorter journeys, neighborhood destinations."

"Strongly Disagree" Segment (n=7)

This segment of respondents felt that procedures for unmanned aircraft need to be stricter than for manned aircraft, and that there was still much unknown about potential UAM applications and operating environments.

- "A common set of standards should apply to all vehicles."
- "Unmanned has a great potential for catastrophes."
- "There are issues that have not even been discovered yet, until much more experimentation and validation occurs."
- "Unmanned need to be significantly better than manned vehicles in their safety procedures to generate acceptance and avoid a backlash against the technology."

7

Figure 8 shows the key safety certification standards and regulations that survey respondents feel UAS programs need to comply with. The two most important standards cited were FAA Part 107 (40% mentioned) and FAA Part 23 / EASA CS-23 (37%), with two additional responses have notable mention levels (32% each): DO-178 / ED-12C and DO-254 / ED-80. Note that approximately 15% of respondents said they "don't know" which safety certification standards should be used (i.e. reported as part of 'Other' responses for this question).

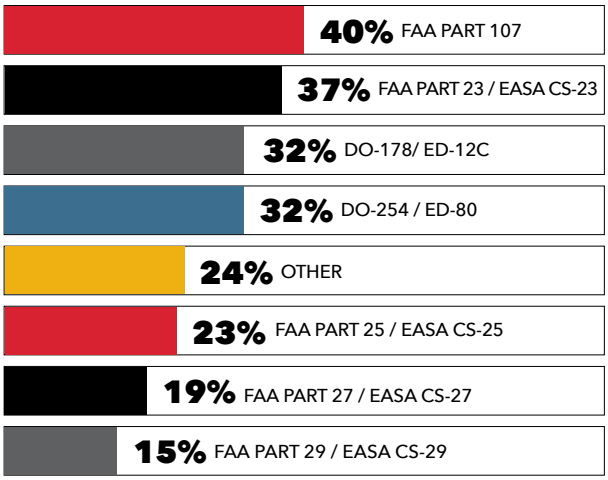


FIGURE 8

When asked "would you consider using certifiable commercial off-the-shelf (COTS) components with certification artifacts", most respondents (80%) said they were likely to use COTS – with 38% saying "Yes, definitely" and another 42% saying "Probably, exploring options" (see Figure 9). Most of the remaining respondents (19%) said "Don't know", with only 1% saying "Unlikely" and none saying "No".

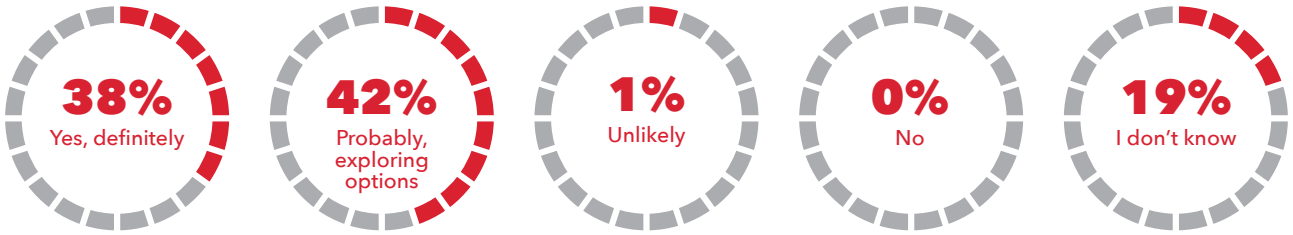


FIGURE 9

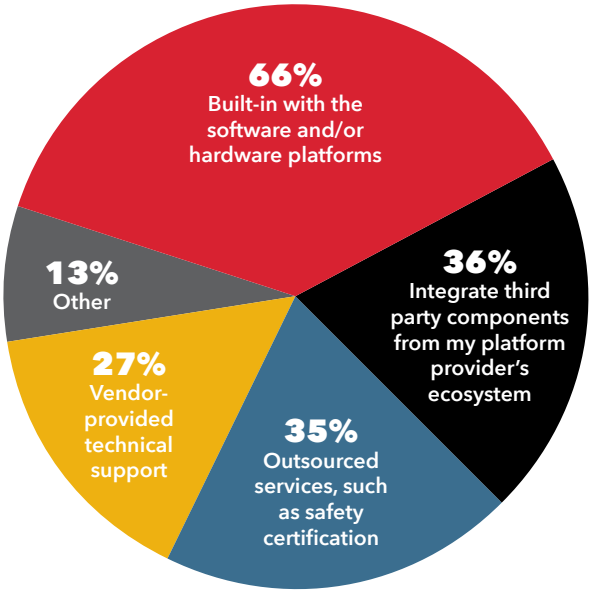


FIGURE 10

At the end of the 'Cybersecurity and Safety Compliance Issues' portion of the survey, respondents were asked about their preferred methods of obtaining safety and security technology for UAM systems. Figure 10 shows that two-thirds of respondents favored that safety and security technology be 'Built-in with the software and/or hardware platforms' (66%), with the next most preferred options being to 'Integrate third party components from my platform provider's ecosystem' (36%) or to use 'Outsourced services, such as safety certification' (35%).

Sub-System Development Issues Related to UAM Initiatives

8 Sub-System Development Considerations

A strong majority of survey respondents (93%) felt that 'sub-systems with (their) unmanned aircraft systems need to run several applications at the same time, e.g. navigation/GPS, collision avoidance, real-time communications,' including 60% that said "Yes, definitely" and another 33% that said "Probably, exploring options." Only 3% said "Unlikely" and another 3% said "No", with only 1% answering "Don't know." **Figure 11** summarizes the results for this survey question, with questions in this overall section of the study generally having n = 89.

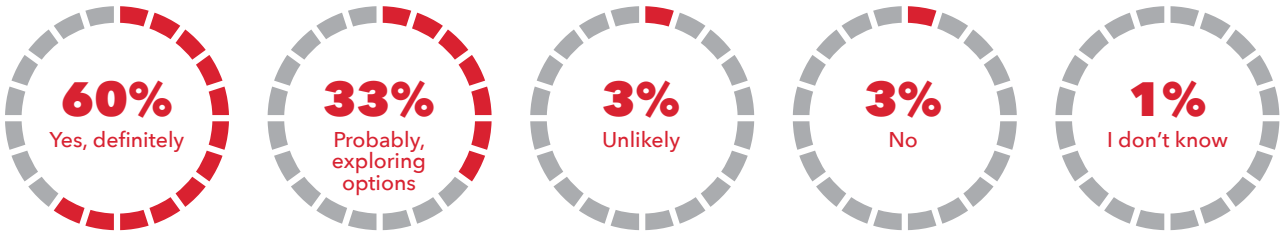


FIGURE 11

The key types of applications that respondents would be 'consolidating and/or adding' when using more than one application on the same sub-system included Real-time (71% mentioned), Safety critical/certified (63%), and Artificial intelligence / machine learning (47%). **Figure 12** shows additional applications mentioned for this survey question.

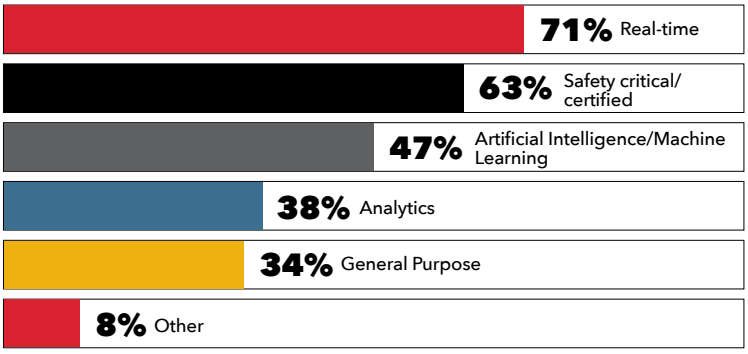


FIGURE 12

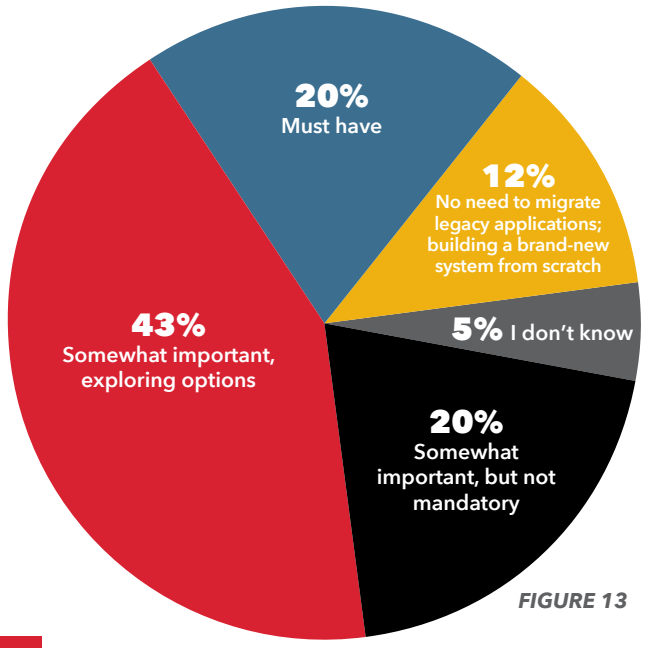


FIGURE 13

Overall, respondents felt that it was important to 'migrate existing applications to (the) current/ next design,' with 20% considering it a "Must have" and another 63% considering it "Somewhat important." Relatively few (12%) said that there was "No need to migrate legacy applications." **Figure 13** provides additional detail related to question.

9 Operating System and Hardware/Processor Considerations

A diverse set of operating systems (OS) were mentioned by respondents as the ones they'd prefer to use for UAM applications; a detailed list of the responses is provided in **Figure 14**. The most frequently mentioned OSes were some form of Linux (61% mentioned), followed by Google® Android® (36%) and Microsoft® Windows® (33%). Note that only 3 Linux OS choices received 20% or more mentions: Red Hat® Linux, CentOS Linux, and Ubuntu Linux.

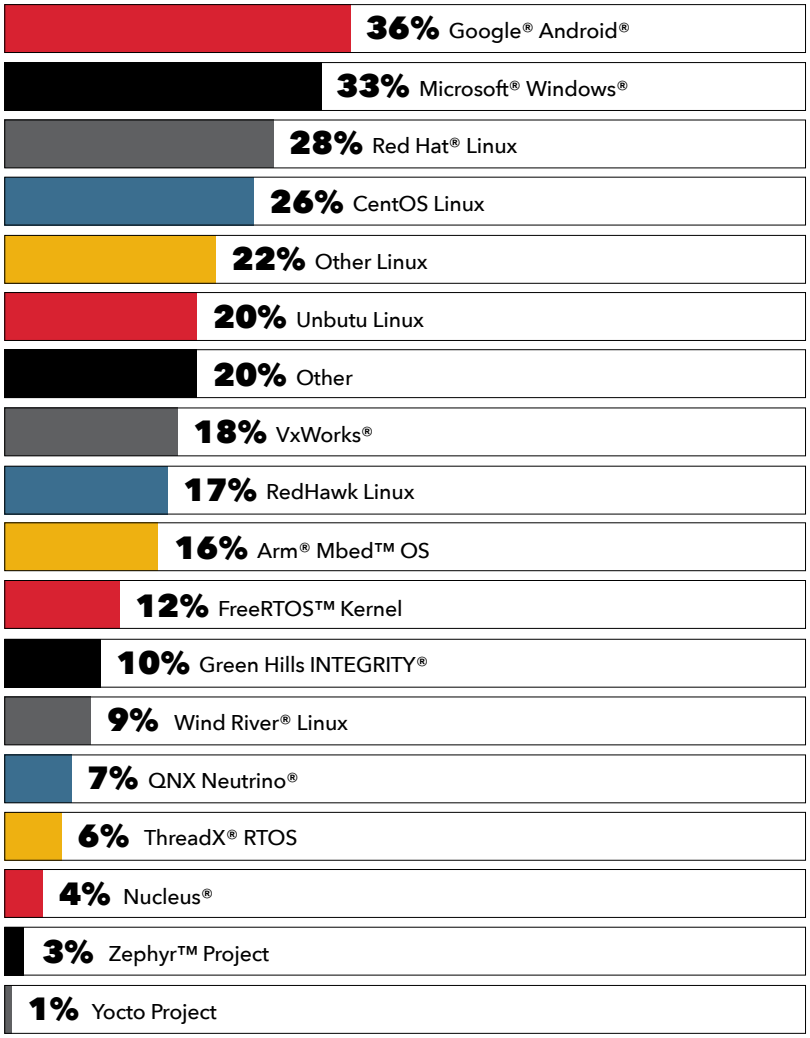


FIGURE 14

Two hardware/processors were most frequently mentioned as ones that respondents were planning to use: Intel Xeon, Core i5/i7 and Atom (62% mentioned) and Arm Cortex A5x, A7x, and R5x (40%); **Figure 15** provides additional detail, with approximately 13% of overall respondents to this question indicating "Don't know" (i.e. part of 'Other' responses).

FIGURE 15

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