Minimum Capabilities List (MCL) Ad Hoc Team

NAC Task 19-1 Report

To be presented to the NextGen Advisory Committee

November 17th, 2020

Table of Contents

Executive Summary 2
Introduction 4
  Background 4
Goal of the MCL 5
MCL Matrix Organization 7
  Baseline Capabilities 7
  Supplemental Capabilities 8
  MCL Column Descriptions 9
Current MCL Fleet Equipage 10
Scope 11
  PBN 12
  Data Comm 13
  ADS-B Out 14
  Resilient NextGen Ops 14
Retrofit 15
Costs and Benefits of the MCL 17
  Methodology 17
  Findings 18
    Cost Data 18
    Benefits Assessments 19
  Cost and Benefit Review 24
Closing & Recommendations 25
Credits and Acknowledgments 27
Glossary of Acronyms and Abbreviations 30
Appendix A 33
  MCL Matrix (Previously Accepted by NAC) 33

Executive Summary

For more than a decade, it has been recognized that successful implementation of the Federal Aviation Administration (FAA) NextGen air traffic control modernization initiative requires an appropriate level of aircraft equipage that enables the use of core capabilities. Initially a sub-task of the Northeast Corridor NextGen Implementation Work Group, the FAA formally tasked the NextGen Advisory Committee (NAC) on October 4, 2019 with developing a recommendation for a Minimum Capability List (MCL).

The MCL is based on a review of current equipage and identifies the core capabilities necessary for future NextGen operations. It can be simply described as, "what avionics requirements would enable an aircraft being ordered today that will be brought into operation in 2025 and beyond to utilize NextGen FAA ATC capabilities?"

The core Aircraft Enabling Capabilities support the following major areas of ATC modernization in FAA's NextGen program:

- Communications - Data Comm, which gives air traffic controllers and pilots the ability to transmit flight plans, clearances, instructions, advisories, flight crew requests, and other essential messages via text, rather than voice.
- Navigation - Performance Based Navigation (PBN) procedures, combining Area Navigation (RNAV) and Required Navigation Performance (RNP), enable an aircraft to navigate using performance standards on any desired flight path within the coverage of ground- or space-based navigational aids and provides the ability to closely monitor performance during an operation.
- Surveillance - Automatic Dependent Surveillance – Broadcast (ADS-B) that relies on GPS satellites to identify the location of an aircraft more precisely than radar.

Representatives from all segments of the manned aircraft operator community, and aircraft and avionics manufacturers, supported by research from MITRE Corporation, conducted the analysis that led to the development of the comprehensive list. The MCL identifies the "baseline" capabilities, as well as other

supplemental capabilities that operators may choose based on needs for access, efficiency or other reasons associated with making equipage decisions.

An important principle of the recommendation is the intent that the MCL is for prospective application, not a retrofit requirement. However, it is recognized that there may be business case driven decisions that will foster the installation of aircraft equipage in the current aircraft fleet.

The consensus contained in this report provides critical policy guidance as decisions are made by the aviation community and the government in modernization of the National Airspace System (NAS).

Introduction

This report will review the efforts of the Minimum Capabilities List (MCL) Ad Hoc Working Group as tasked by the NextGen Advisory Committee (NAC). The group has derived a list of minimum baseline capabilities which all National Airspace System (NAS) users should incorporate on new aircraft purchases. The goals of this report are to:

1) Explain the need for the MCL,
2) Present the MCL items,
3) Clarify to whom the MCL applies, and
4) Present a high-level outline of MCL costs and benefits

Background

The aviation community has long recognized the need for a list of common aircraft performance capabilities which would allow stakeholders to benefit from NAS modernization and improvements. Without a clear understanding of the correlation between modernization and the common aircraft capabilities required to leverage it, time and resources have been poorly spent. As a result, operators have developed fleets whose performance capabilities vary greatly, which we describe as, “Mixed Equipage.”

Mixed equipage makes it difficult to modernize the NAS. This is reflected in more than half of the NextGen Implementation Working Groups (NIWGs) working on NAC taskings citing mixed equipage as an issue in their findings.

Building on work started in early 2019 by a Northeast Corridor (NEC) NIWG sub-group, a “capabilities” matrix was formed which would eventually become the basis for a comprehensive list of baseline and supplemental forward fit capabilities. When the NAC was briefed on this work in late 2019, they responded with Tasking 19-1: NAS Aircraft Minimum Capabilities List, which commissioned a group of government and industry subject matter experts to identify a list of common aircraft capabilities which both FAA and aircraft operators could support. This report summarizes the work of the MCL working group.

Goal of the MCL

The overarching goal of the MCL effort was to drive industry consensus on what equipage is critical to advancing the NAS into a NextGen state. The following issues were considered:

- Determine which critical SMEs were needed to fully address the issue
- Create a matrix which would form the basis for the required equipage
- Commit to progress on a forward-fit only solution
- Consider what data decision makers need to adopt recommendations
- Determine to whom the MCL should apply
- Define a cost/benefit structure
- Stress the importance of the government-industry partnership to ensure consensus and facilitate progress

The group used existing FAA material as a foundation. The PBN NAS Navigation Strategy and Data Comm Services Roadmap specifically informed the effort and built upon previously established goals for the future of the NAS.

Broad industry participation was needed to ensure that SMEs were available to discuss which capabilities were needed to achieve the desired end state. Operators, aircraft and avionics manufacturers, aviation organizations, labor unions, and government were all represented.

The final product of this collaborative effort is known as the MCL Matrix, which will be reviewed in detail later in this report. The working group also agreed that the required MCL equipage would be solely based on a forward-fit model, and that the group would only provide a framework for retrofit should the benefits later become appealing.

Another important task to achieve our goal was the definition of a “scope” structure, so operators would know to whom the MCL would apply.

Finally, the working group needed to communicate its results in a way which would encourage adoption. This included a cost and benefit analysis which underscores the importance of the government-industry partnership in the MCL.

This partnership can facilitate increased confidence that NextGen facility and infrastructure improvements will be reciprocated by operator equipage investments which deliver the desired NextGen performance capabilities.

MCL Matrix Organization

The MCL document exists as a Microsoft Excel file with seven (7) tabs. These are:

- Baseline Capabilities
- Supplemental Capabilities
- Scope
- Retrofit Applications
- Cost/Benefit Analysis
- NSG Airports (Reference), and
- Glossary

The MCL Matrix is listed on the first two tabs and will be described in this chapter. The other tabbed topics are covered in subsequent chapters of the report.

Baseline Capabilities

The working group considers these four (4) capabilities to be the minimum preferred equipage to fully participate in NextGen airspace initiatives from 2025 and beyond.

The working group recommends that the equipment listed below would be designated as standard equipment by OEMs on all newly manufactured aircraft. Not only will the goal of lowering the mixed equipage ratio in the NAS be achieved, but it will also reduce friction to further implementation of NextGen airspace improvements.

1) PBN: Required Navigation Performance (RNP) for various phases of flight, in addition to Radius to Fix (RF) turn, Scalability, and capability to couple the Autopilot to Baro/VNAV guidance down to LNAV/VNAV minimums
2) Data Comm: FANS-1/A with "Push to Load" over VDL Mode 2 with multi-frequency
3) Surveillance: Mandated ADS-B Out functionality
4) Resilient NextGen Ops: DME/DME/IRU Navigation

The Working Group would like to draw particular attention to three (3) notes which appear at the bottom of the Baseline Capabilities tab:

1) Existing equipage should be maintained - These NextGen technologies are sometimes not equipped on new delivery aircraft. They are not listed as replacements to current equipage like ILS, VOR, etc. but should be viewed as required capabilities above and beyond the normal avionics suite commonly selected today.
2) Existing equipage which could be retired - The group wanted to also recommend equipage which may no longer be of value. One item in this category would ADF equipment.
3) Integration of NextGen Comm/Nav/Surveillance capabilities is extremely important, and no single NextGen enabling category should take precedence over another. All MCL capabilities should be considered integral to each other.

Supplemental Capabilities

These represent an additional thirteen (13) enabling capabilities in addition to those covered on the Baseline tab. The group acknowledges that these capabilities may add value to an operation in specific conditions or circumstances. Although not strictly required to participate in the NextGen NAS, targeted investment in one or more of these applications may increase the margin of safety, enable more efficient operations, or enable operations where none could be accomplished without. The group encourages each operator to review this list and consider investment if it benefits their operation.

1) RNP-AR
2) LPV
3) GLS (CAT I/II/III)
4) HUD
5) Airborne Access to SWIM
6) EFVS/CVS (for credit)
7) Enhanced Position Source (EPS)
8) Tightly Coupled IRU
9) Synthetic Vision (for credit)
10) ADS-B IN / Cockpit Display of Traffic Info (CDTI)
11) Time of Arrival Control (TOAC)

12) ACAS-X
13) DME Navigation to support RNP in all phases of flight

MCL Column Descriptions

Listed below are expanded descriptions of each column:

1. **NextGen Enabling Category**: general description of enabling capabilities
2. **Aircraft Enabling Capability**: the particular enabling category function set desired in NextGen NAS airspace
3. **Key Missing Components**: desired NAS 2025 functionality commonly missing in today's NAS user aircraft
4. **Guidance**: FAA Regulatory and/or RTCA Technical guidance which fully defines the Aircraft Enabling Capabilities
5. **Ops Approval Required / Ops Specification**: Specific FAA Ops Spec approvals required for Aircraft Enabling Capability
6. **Equipment Specification**: FAA Technical Standard Orders (TSO) which apply to required equipment
7. **Benefits**: Improved functionality or "gains" realized in NAS operations
8. **Example Use Cases**: specific NAS applications of realized Benefits
9. **Areas Receiving Benefit**: Specific Areas of Operation (and sometimes specific example airports) which will realize "Benefits"
10. **Ground Investment**: FAA investments on the ground infrastructure
11. **Risks to ROI**: possible impediments, and therefore risks to investment in the Enabling Capability
12. **Risks of Not Equipping**: What will happen (or continue happening) if operators choose not to equip
13. **Possible Future Benefits**: benefits for which specific criteria or guidance is not yet developed, but which have shown keen potential or FAA / industry interest
14. **Desired Improvement**: Specific applications of benefits
15. **Global Requirements**: prospective impact on the global air commerce community, and likely areas requiring further discussion with international regulators and operators. Consideration for the global community could allow adoption of the MCL outside the U.S.

Current MCL Fleet Equipage

A review of mainline and regional aircraft was conducted and the charts below show equipage levels as of Q4, 2019 (Pre-COVID numbers):

Air Transport Aircraft	Total Count	Baseline MCL						
		Approach					Terminal	Enroute
			A-RNP		RNAV (GPS)			
		RNP AR	Capable	Ops Spec	Coupled VNAV	Advisory VNAV only	RNP-1 w RF	RNP-2
WB/NB	5,355	4,827	4,859	4,088	5,130	225	4,859	5,303
Regional	2,033	702	887	509	1,106	927	887	2,021
WB/NB	5,355	90%	91%	76%	96%	4%	91%	99%
Regional	2,033	35%	44%	25%	54%	46%	44%	99%

Air Transport Aircraft	Total Count	Baseline MCL	
		Data Comm	
		DCL	Enroute CPDLC
WB/NB	5,355	3,603	3,134
Regional	2,033	34	31
WB/NB	5,355	67%	59%
Regional	2,033	2%	2%

Air Transport Aircraft	Total Count	Baseline MCL
		Resiliency
		DME/DME/IRU
WB/NB	5,355	5,242
Regional	2,033	705
WB/NB	5,355	98%
Regional	2,033	35%

Scope

One of the larger questions the working group addressed was to whom should the MCL apply? This was a difficult question, as a delicate balance must be struck in its response. If too many operators are included, the MCL would likely encounter fatal resistance to acceptance. Conversely, if too many operators are excluded, then the mixed equipage issue isn't resolved to its fullest potential.

The working group determined that the best way to erect scope around the MCL was by isolating the Baseline capabilities and applying a set of filters unique to each. Recall that our MCL goal is to solve "mixed equipage" issues. This solution does not exclude seeing some operations scoped out of the MCL even though the operators fly fully equipped aircraft. The group also applied some latitude to allow a limited presence of mixed equipage so as not to place undue burden on small operations, as it is considered that these will not significantly impede NextGen efforts.

The group used three primary filtering methods in determining to whom a particular capability would apply:

1. **Airports Flown To or From**. This concept was taken from the PBN NAS Navigation Strategy and the Navigation Service Group (NSG) concept. The role an airport plays in the NAS is used as the primary basis for its assignment to one of six NSG categories. The group considered NSG-1 and NSG-2 airports only. These two groups include approximately 74 airports in the "busiest large hub" and "remaining large hub" categories and are defined by the relatively high number of IFR operations and U.S. enplanements.
2. **Type of Airspace Flown**. This is as simple as it sounds. The group used rule airspace as a defining limit in some filters.
3. **FAA Operations Part or Aviation Organization affiliation**. The group used FAA Parts (i.e. 91, 135) to limit or define participation and used affiliation with aviation organizations, such as A4A or NBAA, where appropriate.

An extract from the Scope Table is shown below:

Aircraft Enabling Capability	Filter A		Filter B		Filter C
PBN • RNP-2 (Enroute)	Flies to/from NSG 1 - 2	and	Flies in Class A Airspace	and NOT	Part 91
PBN • RNP-1 with RF (Terminal SID/STAR)	Flies to/from NSG 1 - 2	and NOT	Part 91		
PBN • RNP APCH w/ RF (Approach) • A-RNP or RNP AR 0.3 w/ RF (Approach) • RNP Scalability • Autopilot-coupled VNAV	Flies to/from NSG 1 - 2	and	Operators (like Part 91, Part 135, 141, etc) whose scope/tempo of IFR operations would cause mixed equipage issues		
Data Comm • DCL	Flies to/from NSG 1 - 2 with DCL Services	and NOT	Part 91*		
Data Comm • Enroute CPDLC Services	Flies to/from NSG 1 - 2	and	Flies in Class A Airspace	and NOT	Part 91, NBAA
• ADS-B Out - **Mandate**	Rule Compliant				
• Resilient NextGen Ops (DME/DME/IRU)	Flies to/from NSG 1 - 2	and NOT	Part 91, NBAA		

It's important to note that while some operators may find themselves scoped out of the MCL, this doesn't imply that they cannot, or in some cases even should equip.

PBN

In the case of RNP-2, the group that operates flying to or from NSG 1 or 2 airports and above 18,000 feet but not under Part 91 rules will need to equip. This is largely due to RNP-2 being an enroute capability targeting more efficient operations above 18,000 feet.

The next capability, RNP-1 with RF turns, is intended for terminal area procedures, such as SIDs and STARs. This capability is scoped to include operators flying to or from NSG-1 or -2 airports, but not Part 91 operators.

The discussion concerning PBN approach capabilities presented more difficulty to achieve group consensus. Similar to previous capabilities, the group first identified operators flying to or from NSG-1 or -2 airports. The next filter required careful consideration. There are some small operations underway, especially at NSG-2 airports, which should not be unduly burdened; however, the benefits for those who do equip must be preserved. Therefore, the group identified and included only those operators whose scope and IFR operations tempo would create mixed equipage friction. Examples included smaller charter operations or flight schools which primarily operate VFR. Their lack of MCL Baseline capabilities will likely not impact PBN operations and it would be unreasonable to expect them to voluntarily equip. However, if that same small charter outfit or flight school grew to encompass a significant number of IFR operations at the airport, then their lack of equipage could be impactful. In this way, these smaller operators may commence operations without equipping, but may grow into MCL scope if their operations expand.

Data Comm

CPDLC-DCL departure clearance capability required a slightly different approach, as we first clarified NSG-1 or -2 airports "with DCL services." The group excluded those operators who mostly serve NSG-1 or -2 airports which lack DCL services. It should be noted that Part 91 operators were excluded. However, while AOPA did not want to obligate its members to expensive FANS 1/A investment, it should be noted that the GA community is keen to investigate alternate methods of receiving departure clearances. For example, should future DCL clearances ever become available on an EFB or smartphone app, AOPA may re-engage with more interest in this Baseline capability.

Scope for enroute CPDLC Services basically mirrors that of RNP-2, the only difference being the addition of NBAA operators to the exclusion filter. Similar to Part 91 operators, acquiring integrated FANS 1/A equipage might prove too costly for some, and this mixed equipage element is frankly not harmful to the investment of those who do equip.

ADS-B Out

As ADS-B Out is an FAA mandate, this filter simply mirrors the FAA rule discriminating whether one needs to equip.

Resilient NextGen Ops

The Baseline capability of GPS resiliency targets operators who fly to or from NSG-1 or -2 airports, but not Part 91 or NBAA operators. This reflects that, up to now, GPS failure events have largely impacted Part 121 scheduled operations.

Retrofit

Retrofit of existing aircraft was a topic which the working group initially sought to avoid as it was not within the scope of the NAC tasking. The MCL continues to be focused on forward-fit only, and this section does **not** change that fact.

However, during deliberations, some participants showed interest in retro-fitting newer aircraft to be MCL-compliant. This applies particularly to aircraft which may have been purchased within the last 5 years and have many years of service life ahead of them. These aircraft could delay the success of the MCL since they are newer aircraft lacking Baseline equipage.

With that in mind, the working group decided to address retro-fit in a creative way. While the group is not recommending a retro-fit, the group examined capabilities which, if absent on an aircraft, could be an impediment to the NAS.

The group broke down all the MCL Baseline capabilities in the table shown below and then created a column labelled “NAS Impediment If Not Equipped.” In this column, an MCL Baseline capability is listed if its absence would be problematic in the future.

The group hopes that in this way it can assist an operator wishing to invest in a retrofit to make informed decisions regarding how that investment is spent.

NextGen Enabling Category	Aircraft Enabling Capability	NAS Impediment If Not Equipped
Performance Based Navigation	• RNP-2 (Enroute) • RNP-1 with RF (Terminal SID/STAR) • RNP APCH, A-RNP or RNP AR 0.3 with RF and Automated RNP Scalability (Apch) • Autopilot-coupled VNAV	• RNP-2 • RNP-1 w/ RF • A-RNP w/ RF • Autopilot-coupled VNAV
Data Comm	• FANS-1/A over multi-freq VDL Mode 2 with "Push to Load"	• DCL in tarmac constrained airports • Future enroute services
Surveillance	• ADS-B Out - **Mandate***	
Performance Based Navigation, Low Vis Ops, Surveillance	• Resilient NextGen Ops (DME/DME/IRU)	

* Note: For operators who were granted Exemption 12555, position source equipage changes are expected over the next five years which may provide the opportunity to retrofit additional MCL Core and Optional capabilities.

Costs and Benefits of the MCL

One of the key elements associated with the third sub-task, *Recommendations on Steps to Encourage MCL Adoption*, is to provide an understanding of the investment outlays and potential return associated with equipping and training for MCL capabilities. From previous discussions with the NAC, it is clear that decision-makers must have reliable information on the costs and benefits associated with each component of the MCL before operators will be able to make equipage commitments.

Methodology

The MCL task team developed the following approach to develop forward-fit cost and benefit information associated with the baseline capabilities in the MCL.

- Costs: Several of the OEMs participating on the MCL task team were asked to provide cost figures for the capabilities in the MCL. This data was to be provided to MITRE, who would then organize and de-identify the data. To be most useful, information from at least two OEMs was required, but input from three OEMs would be preferred.

- Benefits: While there are many projections for benefits associated with MCL capabilities and more broadly with NextGen, these estimates are often dependent on variables which cannot be replicated in the actual operation. The MCL task team determined that a more reliable source of benefits data would be assessments associated with actual implementation of the MCL capabilities. Two sources for these assessments were identified. First, NextGen equipage has been discussed within the NAC for many years. In some cases, those presentations included benefits assessments. That material was referenced to support this subtask. The second and more prominent source for benefits information is the work of the NAC's Joint Analysis Team (JAT). The JAT's responsibility is to provide FAA/Industry consensus assessments of the outcomes associated with implemented NextGen commitments.

Findings

Cost Data

The Working Group asked MITRE to aggregate, de-identify, and analyze pricing information from industry, and then report the results. This was done since MITRE could collect sensitive pricing data utilizing existing NDAs in place with industry and MITRE's history of performing similar roles in previous NAC and other industry/FAA forums.

All information requested, the nature of the information provided, and scope were determined by the working group. MITRE was not asked to contribute to the determination of the information collected, but rather to just aggregate and de-identify the information provided. Below are the results:

<u>Average costs across all models:</u>

- PBN (RNP AR) = $50,000
- DataComm = $94,000
- Surveillance = $13,450
- Resiliency = $0

<u>Raw Range of Costs:</u>

- PBN Baseline Item
  - Range = $0 (Basic) - $317,600
    *Some Narrow body/Regional aircraft and widebody aircraft indicated the capability is basic and therefore pricing range is applicable to the full range of forward fit aircraft
- DataComm (FANS 1/A, VDL Mode 2 with push to load)
  - Range = $0 (Basic) - $318,522
    *All Narrow body/Regional aircraft had a priced option, while only some of the widebody aircraft had priced options (Not all widebody are Basic)
- Surveillance (FAA ADS-B out mandate compliant)
  - Range = $0 (Basic) - $88,000
- Resilient NextGen Operations (DME/DME with IRU)
  - Range = $0 (Basic)
    *All respondents indicated that all in-production aircraft models are fitted with this equipment as part of the Basic aircraft

The range of combined MCL capabilities across all models can vary from $0 to $448,000 per aircraft. Average total cost across all aircraft submitted is $158,000. Important points to remember:

- These are un-negotiated, catalog prices.
- Some aircraft models require Buyer Furnished Equipment (BFE) which was not available at the time this report was due.
- Items with ranges starting at $0 were basic, meaning they are already included in the cost of a particular make/model.
- The Working Group only considered forward-fit. In this scenario, costs are amortized over many years through new aircraft payments.

Benefits Assessments

Performance Base Navigation (PBN)

The MCL task team identified a number of expected benefits from PBN enabling technologies over a myriad of applications in all phases of flight. These applications include RNAV-RNP arrival and departures, Established on RNP (EoR), Optimum Profile Descents (OPDs), RNAV Q/T/Y routes, LNAV/VNAV approach minima, and instrument approaches where ground based NAVAIDs do not exist. Expected benefits from PBN include:

- Additional flight efficiency, such as reduced track miles and more fuel-efficient flight profiles
- Additional throughput enabled by precise, deconflicted arrivals and departures
- Enhanced safety with more predictable flows and stable approaches

The JAT has completed four studies of implemented PBN capabilities associated with the NextGen Joint Implementation Plan. This included analyses of arrival and departure procedures as part of the North Texas Metroplex, EoR at DEN, OPDs at BOS, and OPDs at GYY.

In October 2017[1], the JAT presented the results of its analysis of OPDs implemented at Boston. For the new OPDs, the following benefits were observed:

[1] Meeting summary from the October 4, 2017 NAC meeting, RTCA.

- Fewer Level-offs on arrivals – prior to OPDs aircraft were leveled-off multiple times from enroute to 11,000 ft. After the OPDs were implemented level-offs were kept at 23,000 ft and above.
- For flights that reach cruise altitude outside 200 NM from Boston, vertical profiles improved through increased proportion of continuous descent operations, and shorter time and distance in level flight. Approximately 9.8 gallons fuel savings per flight are attributable to the OPDs.
- For flights that do reach cruise altitude inside 200 NM (includes flights from New York area to Boston), vertical profiles improved through shorter time and distance in level flight. Approximately 6.5 to 8.1 gallons fuel savings per flight are attributable to the OPDs.

The JAT was unable to quantify benefits for the OPDs at GYY. However at the same NAC meeting in October 2017, Boeing Executive Flight Operations presented qualitative benefits, including enhanced safety and efficiency.

In October 2016[2], the JAT presented findings on North Texas Metroplex and Denver EoR implementations. For the North Texas Metroplex, the JAT found the following:

- The Metroplex project did segregate arrival routes between DFW and DAL and added route structure where flights were previously vectored.
- Flight distance increased slightly within 300 nm but flight time was slightly reduced.
- Level segments were reduced and continuous descents increased, particularly for DFW.

In February 2017[3], the JAT updated its findings on the North Texas Metroplex to include fuel savings. DFW arrivals saved $4.5-6.5M annually from reduced level offs, but due to increased flying distances, overall fuel cost for DAL increased by $0.8M annually.

For the DEN EoR implementation, the JAT found that EoR increased utilization of RNP AR approaches from 5.8% of arrivals to 6.6% of arrivals to Denver, an

[2] Meeting summary from the October 5, 2016 NAC meeting, RTCA.
[3] Meeting summary from the February 22, 2017 NAC meeting, RTCA.

increase of 12%. Total distance savings increased to over 52,000 nm annually and flight time savings increased to 282 hours annually.

For the MCL task team benefits discussions, the FAA provided additional information about RNP usage at DEN during 2019. For flights flying the RNP procedures (about 23%) in VMC, the average distance flown on the approach was 22.2 nm verses 30.1 nm for aircraft not flying the RNP procedures. In IMC, the average distance flown was 21.8 nm flights using the RNPs verses 43.8 nm for flights not using the RNP procedures.

There is an obvious and direct correlation between the benefits (time and distance) experienced by equipped RNP operators and the procedure utilization rates. MITRE conducted an analysis[4] for the MCL task team and determined that highly equipped carriers have higher RNP AR utilization rates for their authorized aircraft. Operators with fleets that are more than 75% equipped (and authorized) see utilization rates three times that of carriers that are less than 50% equipped. MITRE's analysis also illustrated how RNP utilization correlates strongly with runway traffic level (see Figure Y). This occurs primarily due to merging and spacing challenges between RNP AR RF leg arrivals and straight-in or non-RNP AR authorized downwind traffic. It is interesting to note that RNP utilization increased sharply with post-COVID declines in traffic level.

[4] MCL Discussion: RNP Utilization Factors, MITRE Corporation, Jul 6, 2020.

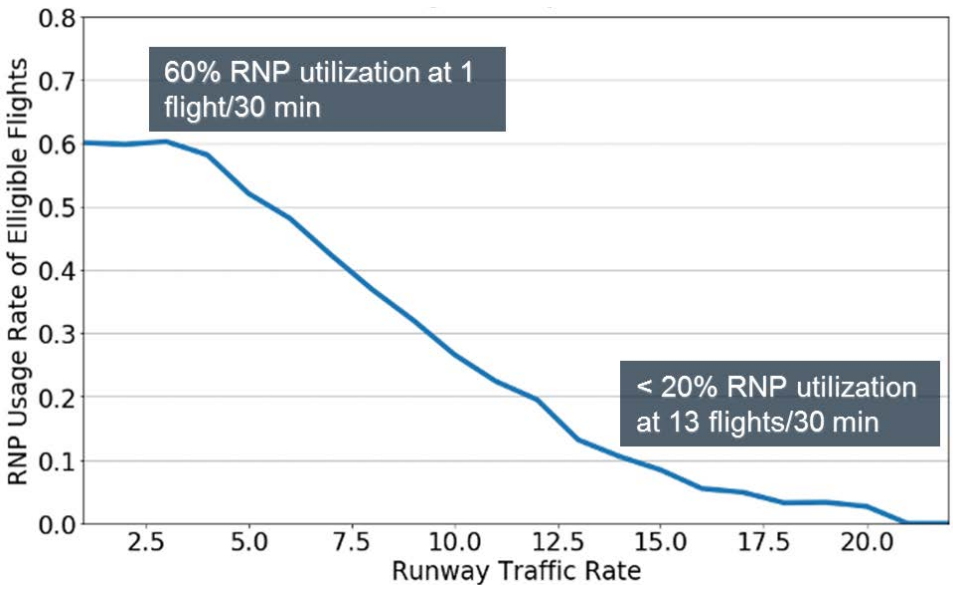

Figure Y. Denver RNP Utilization Rate by Traffic Level in 2017

Data Communications

As part of the MCL task team's deliberations, the following benefits are expected from implementation of tower and enroute data communications.

- On the ground, clearances can be delivered more efficiently with reduced communication errors, resulting in shorter taxi-out times.
- While enroute, re-routes can be accommodated and delivered more accurately, efficiently avoiding weather and congested airspace, resulting in more efficient routing.
- Overall, data communications reduces voice communications, read-back errors, and frequency congestion, resulting in enhanced safety.

At the October 2017 NAC meeting[5], the benefits of pre-departure route revision clearances delivered through data communications were presented. The FAA's data included the following:

- For a sample of airports, taxi-out savings between 0.2 minutes to 8.5 minutes per flight (average 3.8 minutes).

[5] Meeting summary from the October 4, 2017 NAC meeting, RTCA.

- Looking at the network of one large airline, an average taxi-out benefit of 2.8 minutes per flight was identified.

At the same NAC meeting, Southwest Airlines presented data for a three month period in 2017. Over this time period with 73% of its fleet equipped, Southwest experienced a reduction of 13,725 taxi-out minutes.

The Data Communications NextGen Integration Work Group (NIWG) presented the following benefits data to the NAC in August 2020[6], showing achieved benefits from both Tower and Enroute implementations.

- Over the last four years (2016 to present) Tower data communications departure clearance benefits have saved over 2 million minutes of radio time and prevented over a 124,000 read-back errors, enhancing safety. The capability has saved over 1.5 million minutes of airspace user time and over 18 million kilograms of CO_2 Emissions.
- Since 2019, Enroute data communications have saved over 136,000 minutes of communications and mitigated over 36,000 read-back errors.

Surveillance

Since the equipage associated with the Surveillance NextGen Enabling Technology in the MCL was part of the ADS-B Out January 2020 mandate, operational benefits have yet to be enumerated, and therefore specific realized benefit information is not available. For completeness, the following qualitative benefits statements were included in the MCL task team deliberations.

- Improves surveillance in non-radar areas (including surface) and enables reduced spacing, and in select situations reduced separation standards (e.g., 3NM enroute separation)
- Provides more accurate aircraft position data into ATC automation and TFM tools; will enhance safety and increase effectiveness of flow management; more frequent update rate
- Serves as a foundation for ADS-B In and its associated applications, including interval management.

[6] NAC Read-ahead materials for the August 6, 2020 meeting

Resiliency

The aviation community has suffered events which were the result of a loss of GPS onboard the aircraft. These can be the result of GPS hardware/software bugs or jamming of the GPS signal.

Disruptions that occurred ranged from aircraft being unable to fly RNAV SIDs and STARs to aircraft being unable to fly extended ILS approaches. While airlines have not publicly disclosed the losses incurred, each operator should consider their own data.

Since this MCL item is now basic (or no cost) on all production aircraft, the working group did not spend time examining the benefit dollars for this baseline capability.

Cost and Benefit Review

This initial assessment of MCL costs and benefits has identified preliminary elements to answer the questions of how much equipping will cost and its expected return on that investment. There are many variables in the cost and benefit equation, such as which aircraft are being purchased and where those aircraft will fly, which make it impossible for the working group to give one set of numbers.

Benefit assessments based on actual capability implementation (vs. modeled benefit projections) is a sound approach for establishing expected return on investment. NAC data and JAT analyses may need to be augmented with other operational assessments to obtain a more complete benefits outlook, specifically for PBN applications. Operators can use the data in this report to help better understand how to build a business case.

Closing & Recommendations

Neither Industry nor the FAA favors a mandate. In contrast, this MCL effort has been a Government-Industry collaboration which makes recommendations for implementing NextGen improvements for all stakeholders while avoiding a mandate.

If this MCL effort results in no action, we will continue to see investments made by both FAA and Industry whose impact is greatly diminished. To avoid this, there must be a point where Industry and FAA come together with a consistent, common goal to implement NAS improvements on a shorter timescale. This cannot be achieved with the status quo, as both Government and Industry priorities can be pulled in opposing directions without a common equipage plan. The MCL is a step in this direction.

The MCL, however, is not a "silver bullet," as the Working Group only seeks a forward-fit commitment. While this represents a less-painful investment than the retro-fit scenario, it also lengthens the window of time required to significantly reduce the mixed equipage impediment.

While many operators have used the COVID-19 reduced demand environment to retire older, less-capable aircraft, this may very well represent an inflection point in NAS fleet equipage, and therefore a unique opportunity to reduce the mixed equipage impediment. If we agree to adopt the MCL and commit to all new aircraft being MCL Baseline capable, a future without the specter of mixed equipage could be a lot closer than we think. **It is therefore considered that there is no better time than now to make this commitment!**

It should also be recognized there are at least two pathways for MCL adoption: 1) The NAC may acknowledge these results in agreement that a forward fit business case is indeed plausible, and subsequently encourage its adoption by their members; and 2) The NAC may encourage aircraft manufacturers to adopt MCL Baseline capabilities as standard on all U.S. delivered aircraft. Some aircraft are already sold this way, and it has helped operators of those airframes to have common equipage across that fleet.

Finally, the Working Group recommends that if the MCL is successfully adopted, that it be regarded and maintained as a living document. Demands on the NAS will evolve and as they do, some MCL Supplemental capabilities will likely be recharacterized as Baseline. Similarly, newly developed technologies will be identified and should be added to the Supplemental list. Regardless, if Government and Industry continually identify and prioritize common goals for the NAS, we will more successfully implement change together in the future.

The Working Group would like to thank its members for their steadfast participation in its effort to move the NAS forward, and equally for their diligent collaboration in the genesis of this report.

Credits and Acknowledgments

MCL Ad Hoc Co-Chairs

Ron Renk	United Airlines
Greg Young	Delta Air Lines

Aviation Organizations

Jack Allen	A4A
Andy Cebula	A4A
Rune Duke	AOPA
Jens Hennig	GAMA
Richard Boll	NBAA
Heidi Williams	NBAA
Bill Whyte	RAA

Government Organizations

Brian Bagstad	FAA
James Daum	FAA
Pamela Gomez	FAA
Chris Hope	FAA
Dave Knorr	FAA
John Maffei	FAA
Caitlin Matulenas	FAA
Barry Miller	FAA
Juan Narvid	FAA
Kimberly Noonan	FAA
Wendy O'Connor	FAA
Arthur Orton	FAA
Mark Steinbicker	FAA
Jamal Wilson	FAA
Natee Wongsangpaiboon	FAA

Vaughn Yates	FAA
Steve Giles	MITRE
Marshall Koch	MITRE
Sean McCourt	MITRE

Labor Organizations

Craig Boxrucker	ALPA
Darrell Pennington	ALPA
Adam Rhodes	NATCA
Jeff Woods	NATCA

Manufacturers

Pascal Joly	Airbus
Jean-Christophe Lair	Airbus
Monica Alcabin	Boeing
Sheila Conway	Boeing
Ben Ivers	Boeing
William Richards	Boeing
Michael McDowell	Collins Aerospace
Charles Wade	Collins Aerospace
Ricardo Teixeira	Embraer
Greg Carlucci	Honeywell Aerospace
William Forstie	Honeywell Aerospace
Chris Collings	L3 Harris
Christophe Hamel	L3 Harris
Phil Keenan	Mitsubishi Aircraft

Operators

David Surridge	American Airlines
Brian Townsend	American Airlines
Mark Hopkins	Delta Air Lines
David Wilson	Endeavor Airlines

Dan Allen	FedEx
Phil Santos	FedEx
Jon Tree	FedEx
Lee Brown	JetBlue
Charles Cook	JetBlue
Richard Buergel	NetJets
Karl von Valtier	NetJets
Rick Dalton	Southwest Airlines
Gary McMullin	Southwest Airlines
Glenn Morse	United Airlines
Jonathan Bonds	UPS
Christian Kast	UPS

Glossary of Acronyms and Abbreviations

8900 Flight Standards Information Management System Documentation

AC FAA Advisory Circular

ACAS-X Airborne Collision Avoidance System

ADS-B Automatic Dependent Surveillance – Broadcast

ADS-B In Automatic Dependent Surveillance – Broadcast (Receiving ADS-B Traffic in the Aircraft)

AFP Airspace Flow Program

ANP Actual Navigation Performance

Apch/apchs Approach(s)

ARINC Aeronautical Radio, Inc.

A-RNP Advanced RNP

Arr arrival

ATC Air Traffic Control

ATN Aeronautical Telecommunications Network

ATSU Air Traffic Services Unit

CAVS CDTI (Display of Traffic Information) - Assisted Visual Separation

CDTI Cockpit Display of Traffic Information (referring to ADS-B In)

Cgs ceilings

Chgs changes

CMU/CM Communications Management Unit

CPDLC Controller Pilot Data Link Communications

CPDLC-DCL Controller Pilot Data Link Communications – Departure Clearances

CSPO Closely Spaced Parallel Operations (referring to FAA 7110.XX #)

CTOP/TOS Collaborative Trajectory Options Program / Trajectory Options Set

CVS Combined Vision System

DA/MDA Decision Altitude / Minimum Descent Altitude

Dep departure

DME-DME/IRU Distance Measuring System / Inertial Reference Unit

EFVS Enhanced Flight Vision Systems

EGPWS Enhanced Ground Proximity Warning System

EoR Established on RNP

EPS Engineered Performance Standards

ERAM Enroute Automation Modernization

FANS 1/A Future Air Navigation System

FIM Flight Interval Management

FMC Flight Management Computer

Freq frequency

GDP Ground Delay Program

GNSSU Global Navigation Satellite System Unit

HAT Height above touchdown

HDD Head-Down Display

IAP Instrument Approach Procedure

IMC Instrument Meteorological Conditions

Ldgs landings

Maint maintenance

MCL Minimum Capabilities List

Mins minimums

MMR Multi-mode receiver

Msgs messages

NAS National Airspace System (U. S.)

Nav navigation

NGSS Next Generation Satellite Systems

OEM Original Equipment Manufacturer

OPD Optimized Profile Descent

PBN Performance Based Navigation

PFD Primary Flight Display

PRAIM Predictive RNAV

Q/T/Y Airborne RNAV Routes

Reqd/reqs required/requirements

RNP Required Navigation Performance

ROI Return on Investment

RTCA DO Radio Technical Commission for Aeronautics - Document

RVR Runway Visual Range

SAPR Safety Assurance Process Requirements

SAPT Service Availability Prediction Tool

SAR Search and Rescue

SBAS Surface Based Augmentation System

Scalability Ability of aircraft to scale indicators for various RNP levels

SID Standard Instrument Departure

Spec specification

STAR Standard Terminal Arrival Route

STARS Standard Terminal Automation Replacement System

Svc/svcs service(s)

SWAP Severe Weather Avoidance Plan

SWIM System Wide Information Management

TBO Time Based Operations

TFM Traffic Flow Management

TIS-B Traffic Information Services – Broadcast

TOAC Time of Arrival Control

TSO Technical Standard Order

UDP Unified Delay Program

VDL VHF Datalink

Vis visibility

VMC Visual Meteorological Conditions

WATRS West Atlantic Route System

Appendix A

MCL Matrix (Previously Accepted by NAC)

NextGen Enabling Category	Aircraft Enabling Capability	Key Missing Components	Benefits	Example Use Cases	Areas Receiving Benefit	Ground Investment
Data Comm	• FANS-1/A with "Push to Load" over VDL Mode 2 with multi-frequency	• CMU/CMF/ATSU • VHF Digital Radios • FANS 1/A capable FMC/FMGC	• Shorter ground delay for clearances • Reduced comm errors • Efficient delivery of complex clearances • Reduce long voice comms • Reduced freq congestion • Accurate re-routes • Weather avoidance • Pilot requested re-routes • Enables TBO • CTOP/TOS	• High rate clearances during SWAP • Efficient wx re-routes • Reduced errors in FMS reroute entries • More efficient routing	• NAS ground ops • Enroute ops	• Development / delivery of Data Comm svcs • Enhanced automation and Decision Support tools • Controller training
Surveillance	• ADS-B Out: **Mandate**	• Transponder • Highly accurate position source with integrity	• Enables 3NM enroute separation • Reduced separation in select situations • Improved surveillance in non-radar areas (+ surface) • More accurate position; more frequent update rate • Improved safety via ATC automation and TFM Decision Support tools • Improved Planning and TFM	• 3NM enroute separation • WATRS operations surveillance • Reduced terminal vectoring due to conflict • Enhanced SAR	• Enroute • Terminal • Non-radar environments • Mountainous terrain	• Ground infrastructure • ERAM/STARS enhancements • Controller training • Reduced Spacing