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Restriction Relaxation Experiments Enabled by URET a Strategic Planning Tool

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Abstract

The User Request Evaluation Tool (URET) is a decision support tool that supports strategic planning by the sector team and is a potential "enabler" for free flight. The tool is used on a daily basis at two en route centers with approximately 750 operational personnel trained in its use. It has replaced strips as the primary tool for controller strategic planning. The next phase in the program is to utilize the capabilities of the tool to migrate toward an ATC system that separates aircraft from aircraft rather than aircraft from airspace. This paper describes efforts to measure the benefit from relaxing certain restrictions due to the availability of a strategic planning conflict detection tool such as URET. These efforts began in May 1999 and will continue through 2000. Operational personnel at the two centers have reviewed the restrictions in effect at each site and identified candidates for relaxation evaluations and possible elimination in the future. Several evaluations have taken place since May 1999 in which the utilization of the URET tool allowed some restrictions to be relaxed, which resulted in aircraft being allowed to remain at altitude for a longer time period. The resulting fuel savings were estimated.

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1 Introduction

The User Request Evaluation Tool (URET) was developed by The MITRE Corporation's Center of Advanced Aviation System Development (CAASD) as a tool to assist the controllers in managing operations in a free flight environment. The tool was derived from the Advanced En Route ATC (AERA) research and is designed to support the sector team strategic planning function.

The tool uses flight plan, track, and wind data as the basis upon which to build trajectories of

the projected flight of controlled aircraft and to indicate possible conflicts up to 20 minutes into the future. The tool functionality and computer-human interface evolved based on user feedback from its initial installation at the Indianapolis Air Route Traffic Control Center (ARTCC) until it was deemed ready for large scale evaluations. The large-scale evaluations required the availability of the tool at all positions in both the Indianapolis ARTCC and neighboring Memphis ARTCC on a daily basis. The primary goal of the daily use URET was to exercise the functionality of the tool to its fullest and to identify enhancement/fixes required to ensure its usability on a national basis. A secondary goal of the daily use URET was to train a proficient controller workforce on the use of the new technology so that the strategic planning capabilities of the tool and the associated benefits to the flying public could be assessed. This secondary goal involves an evolution toward separating aircraft from aircraft rather than separating aircraft from airspace.

The functionality embodied by the URET operation in Indianapolis and Memphis is being refined and will be installed in 5 additional sites as part of the Free Flight Phase 1 (FFP1) program [8]. Figure 1 graphically depicts the sites that will have URET capability by the end of 2002. The methodology developed and tested using the URET prototype to assess benefits will be employed at all the URET FFP1 sites. By the time the five new sites approach operational usage, a plan for achieving user benefits at these facilities will already be in place.

This paper describes efforts to measure the benefit from relaxing certain restrictions due to the availability of a strategic planning conflict detection tool such as URET. The paper will briefly discuss the full range of benefits a conflict detection tool could provide to the aviation community. It will concentrate on the user benefits from relaxing restrictions and specifically on the efforts at the Indianapolis ARTCC and Memphis ARTCC to relax altitude restrictions.

For more detailed information concerning the functions and operational use of URET, refer to the "Free Flight Phase 1 Conflict Probe Operational Description" [3] which can be accessed through the FFP1 or CAASD web site, ffp1.faa.gov or www.caasd.org. Within the paper, the Indianapolis ARTCC and Memphis ARTCC will be referred to by their three letter abbreviations, ZID and ZME, respectively.

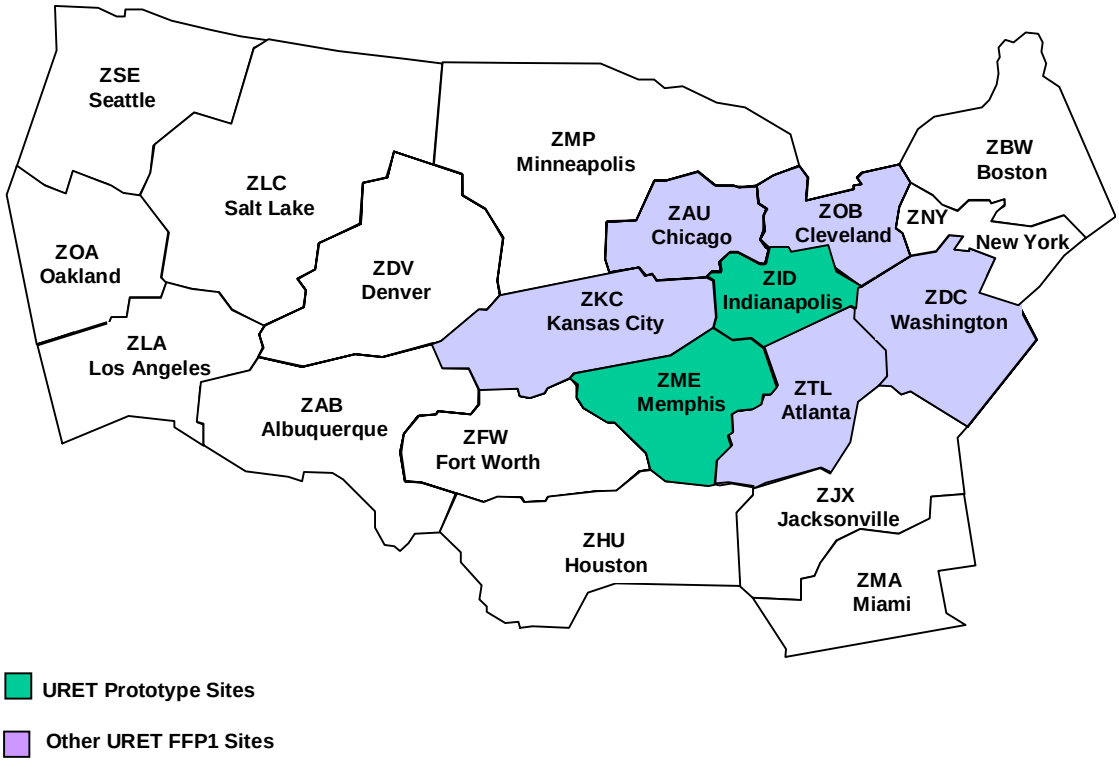

Figure 1. URET FFP1 Implementation Sites

2. URET Utilization

In order to determine what benefits URET is providing, it is important to examine how URET is being used. URET has been in daily use at ZID and ZME since the fall of 1997. Metrics on various URET capabilities are collected and updated on a monthly basis, based on the daily files generated by URET. Over a two-year period, URET has grown from a single workstation to full center operations at both sites. Controller teams recently requested URET be available full time (24 hours a day/7 days per week). Starting in February 2000, URET was made available 22 hours a day/7 days a week at both ZID and ZME. URET is now considered a key component of the controller's toolset. The D-side controller routinely uses URET functionality (e.g. trial planning) to support strategic planning to improve the air traffic flow through the NAS.

In July 1999, tools became available to examine URET usage of the trial planning function and flight plan amendment submission in correlation with traffic counts. It was an oft-spoken belief that URET usage went down as traffic count went up, the rationale being that when traffic density increases the D-side controller does not have time for strategic planning. Figure 2 shows that usage is almost in direct correlation with traffic volume; at least since this measurement began (after 2-way communications for amendments had started).

The metric is calculated by summing all Trial Plans, amendments, and tracked aircraft during a 2-hour interval every day of the month if URET is running. That sum is divided by the number of days URET was available during that time-range. For the month of February in ZID, between 1400Z and 1600Z, on average 195 Trial Plans were generated, 155 of which were entered and accepted by the Host as flight plan amendments. During that same 2-hour interval, an average of 927 flights were tracked in ZID.

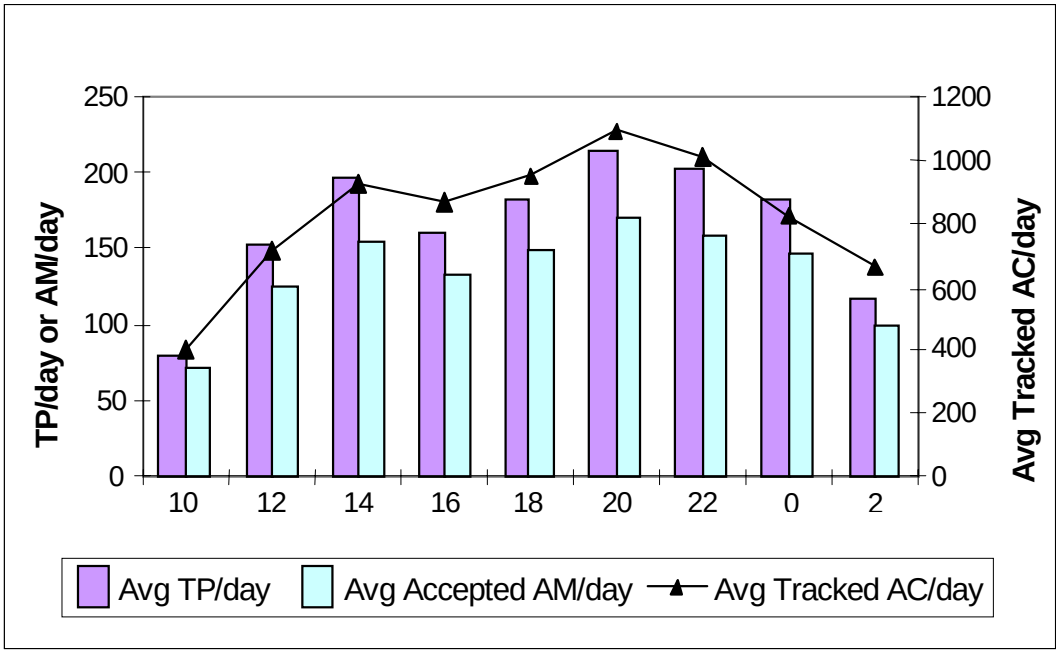

Figure 2. Daily Average Counts of Trial Plans, Amendments, and Tracked Aircraft for ZID in February 2000

The URET prototype has become an integral part of daily-use operations at ZID and ZME. Operational personnel have started to use the reduction in workload provided by the general use of the URET prototype at the centers to provide benefits to the NAS user community.

3 URET Benefits

The objectives of Free Flight are to provide greater flexibility and cost savings to the users without compromising safety. The evolution to Free Flight and the increased reliance on URET and other capabilities are intended to provide tangible benefits early to users during the system's life cycle. The use of URET will enhance safety and FAA productivity, and enable user cost saving benefits. Although the safety and productivity benefits will be identified, the focus of this paper is on user cost saving benefits enabled by restriction relaxation. See [1,2,10] for more information on possible URET benefits.

3.1 Safety Benefits

A number of studies of operational errors suggest that the widespread use of URET can produce significant improvements in safety of the NAS [7]. En route operational errors occur when two aircraft under radar control by en route controllers violate specified separation standards (5 nautical miles lateral or 1,000 or 2,000 feet vertical). If the cause of violating these standards was a mistake on the part of the radar controller, this event is called an operational error.

URET predicts aircraft to aircraft conflicts and warns the controller in the sector in which the violation is expected to occur up to 20 minutes in advance of the predicted loss of separation. Study of URET alerts for scenarios containing recent operational errors from ZID and ZME [9] shows that URET dependably provides alerts with substantial warning times. This after-the-fact analysis indicated that in 16 out of 19 cases, URET provided the D-side controller a warning time of between 2.5 and 13 minutes with an average of 7 minutes.

3.2 FAA Productivity Gains

The productivity gains and reduction in sector workload that URET provides sector control teams are critical for the effective use of the tool. Relief from routine tasks and more efficient management of sector workload are essential aspects of URET that create the opportunity to carry out the strategic planning tasks that will achieve user benefits.

Reduced workload includes:

- Less physical movement to manipulate and write on strips
- Reduced mental projection of flight paths to determine possible conflicts
- Quicker entry of route amendments into the Host

URET is the primary source of flight data for the sector. The flight trajectory is a more accurate model of an aircraft's predicted flight path than what is presented on a paper strip. The trajectory is continually adjusted using Host track information, wind and temperature. These changes are automatically made to the displayed information.

The conflict probe and trial plan results generated by URET provide new, accurate, continuously updated future situation awareness data. When notification of a predicted conflict is received, the controller may elect to trial plan potential solutions. The controller is able to see the impact of potential solutions in terms of creating other conflicts. Although the sector planning decision process with URET remains a mental assessment and judgment by controllers, URET relieves controllers from performing routine, recurring and often time-consuming manual calculations to predict and compare future positions of aircraft [4,5].

URET is used to enter flight data amendments and flight plans into the Host. The graphic display of an aircraft's trajectory and the point and click capabilities of the URET CHI provide a significant time savings for controllers using URET to generate a route amendment. URET automatically formats a flight amendment for Host, and provides the option to submit it to Host with a single action. The ease with which route amendments can be generated and submitted to Host is expected to result in flight plans that better reflect the intent of the aircraft.

The results of these productivity improvements are being examined as to their effects on throughput. Preliminary data on traffic loads indicates that with URET use, sector air traffic counts have increased while sector transit times have either held steady or have decreased. This aspect of the results is still under investigation and may be reported on at a later date.

3.3 Restriction Relaxation

URET has been postulated as a tool that will enable aircraft to fly more user preferred flight profiles. Due to its extended look ahead, the tool will enable aircraft to fly longer directs and enable proposed flight amendments to be evaluated on a real time basis. At sector and facility boundaries, there may be the potential to relax certain restrictions during all or portions of the day due to the better data inherent in URET and the capability of the tool to project aircraft trajectories into and out of the sector/center airspace. This enables controllers to separate aircraft from aircraft rather than aircraft from airspace. Altitude restrictions force aircraft to fly at a less than optimum altitude; thus increasing fuel burn, time in the air and operating costs.

Restrictions are in place to better manage flows between sectors or centers. There are about 190 static altitude restrictions in ZME airspace, and about 370 in ZID airspace. They primarily help with the separation of aircraft. They also support an orderly transition of traffic through sectors and help controllers at each of the sectors handle the altitudes they're responsible for without making decisions for the sectors below them. Restrictions are a form of coordination that everyone understands; they keep aircraft climbing and descending in a way that everyone expects. URET capabilities provide better and more accurate information to the D-side controller, which may enable the controller to dynamically relax restrictions in accordance with existing and planned traffic flows. The URET provided conflict information will alert controllers to potential conflict situations in a free flow environment that could thereby reduce the need for static restrictions imposed on the flows.

3.4 Operational Evaluations of Restriction Relaxation

The purpose of the operational evaluation of restriction relaxation is to determine if the strategic planning capabilities of URET will allow certain static restrictions to be relaxed during a portion of the day at ZID and ZME without adverse impact to controller operations or to the overall air traffic flow. The goal of the first evaluation, held in May 1999, was to determine if URET enables controllers managing the arrival stream to Nashville (BNA) and Louisville (SDF) to relax crossing restrictions and if there is measurable benefit in relaxing the restrictions.

First Evaluation: 27 May 1999

On 27 May 1999, an evaluation of the lifting of altitude restrictions between ZID and ZME took place. Arrival restrictions into Nashville (BNA) in ZME airspace and into Standiford (SDF) in ZID airspace were lifted for a 2-hour period, from approximately 10:00 am to noon local time. For a complete analysis of this evaluation, please refer to the CAASD report, [6]. The following summarizes the main conclusions of the evaluation.

Jet aircraft going to BNA are normally restricted to FL200 or below crossing from ZID to ZME airspace (see Figure 3). Typically under normal operations with the restriction in place, the aircraft would traverse either Pocket City or Louisville sector, and be handed off to the low altitude ZID sector Evansville/New Hope. The controller working Evansville/New Hope would clear the aircraft to cross the facility boundary at 16,000 feet. The interfacility handoff would be between Evansville in ZID and Bowling Green in ZME. Bowling Green would then clear the aircraft down to cross HEHAW at 10,000 feet.

During the conduct of the evaluations (URET operational and restriction relaxed) for BNA aircraft, the D-side of the controlling high altitude sector would do a "show all" in which all predicted conflicts would be depicted on his URET screen. (Normally only conflicts predicted to occur within his own sector are highlighted on his URET display.) If the "show all" revealed no conflicts, the controller issued a clearance to the pilot of the BNA inbound flight for a discretionary descent to cross HEHAW at 10,000 feet. The aircraft would be handed off (within ZID) to the Evansville/New Hope low sector (even if the aircraft remained at FL310). As the aircraft approached the ZID/ZME facility boundary the aircraft would be handed off from the Evansville/New Hope sector to the Bowling Green ZME sector. If the aircraft remained at altitude and would enter the Campbell high sector in ZME, the Louisville High sector controller would make the request for point out to the ZME Campbell High sector.

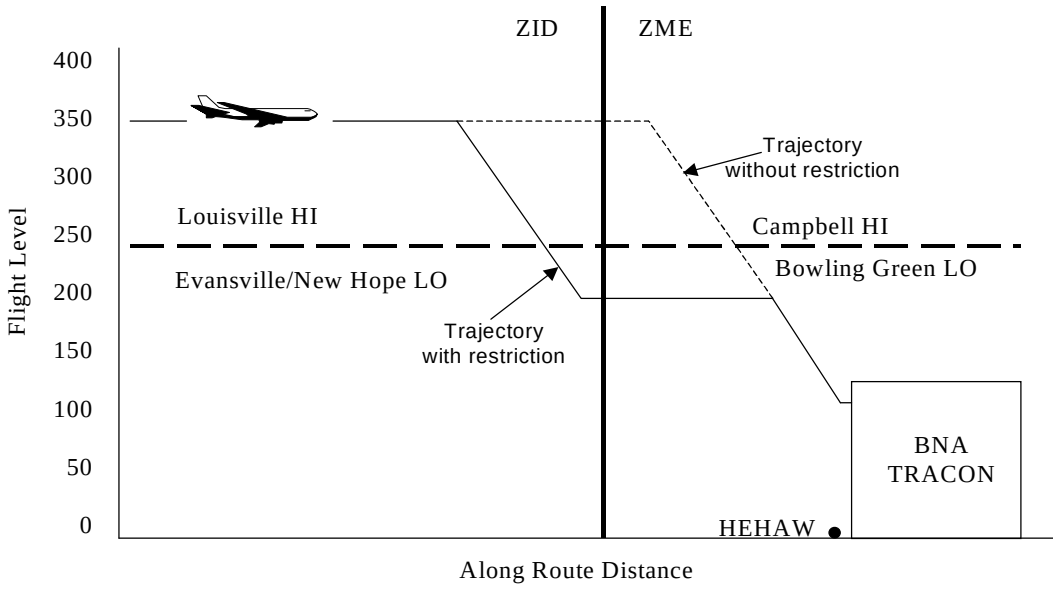

Figure 3. Approximate Altitude Profile for Trajectories with and without ZID/ZME Crossing Restriction for Nashville Arrivals

The air traffic recorded data from 27 May 1999 was analyzed in terms of URET trajectory comparisons and track comparisons. These comparisons were made between URET trajectories with and without the subject restrictions, and recorded tracks, with and without these restrictions.

There were 12 flights eligible for the URET trajectory analysis. The Top of Descent along Route Distance shows that aircraft stayed higher for an average of 38.7 nautical miles when the restriction was turned off than with it on. The Along Route Time shows aircraft stayed higher for an average of five minutes farther down route when the restriction was turned off.

Track analysis compared seven common flights on 20, 26, 27 May 1999. It took the same flights on three different days, two of the days, 20 and 26 May, the aircraft were kept at the restricted altitude. On 27 May, during the evaluation, the aircraft descended at their own discretion. Actual comparison of the tracks shows that flights on 27 May crossed the restriction location an average 5000 feet above the same flights on 20 and 26 May 1999. In addition, they stayed at altitude 3 - 3.5 minutes longer before beginning their arrival descent.

The results of the analysis that followed the temporary relaxation of restrictions were positive and encouraging, both from the traffic analysis and from the operational perspectives. Operational personnel were willing to review other altitude restrictions as candidates for testing and possible removal. Controller feedback from the evaluation provided excellent insights into the conduct of future evaluations. Some significant results were:

- Controllers were uncomfortable clearing aircraft to an altitude they didn't control. Giving discretionary descents below the floor of their airspace was an uncomfortable concept. Through post-evaluation discussion, it was determined that for the next evaluation, the clearance should be limited to the floor of the high altitude airspace and then an early hand-off be effected to the low altitude sector.
- The impact of the high altitude sector receiving the pointout needs to be monitored. During the low traffic conditions under which the evaluation was undertaken, the pointouts were handled. When traffic gets busy and the controller "unables" a pointout, the aircraft will have to descend quickly so as not to enter high altitude sectors' airspace.
- Future selection of restriction relaxation candidates should consider the rationale behind the restriction.

Subsequent to this evaluation it was decided to implement facility teams comprised of operational personnel to evaluate how the use of URET will enable them to change their way

of doing business and possibly relax restrictions during portions of the day on a routine basis. Procedures and benefits teams were established at the two sites. These teams were comprised of sector controllers, supervisors, traffic managers, union representatives and plans and procedures specialists. The teams were chartered to review the static altitude restrictions, identify candidates for temporary relaxation of the restriction that would be enabled by use of URET, plan structured evaluations of the restriction relaxation, evaluate the results, and determine the impact of lifting the restriction on controller workload and on user benefits. If the results were positive, the teams would recommend that a restriction be relaxed during all or a portion of the day when URET was operational.

Both teams assessed relaxing static restrictions with the following characteristics:

- Internal restrictions. The relaxation of internal restrictions does not require coordination with other centers. (In the future, ZID and ZME are planning to cooperate in lifting restrictions that are in place between the two facilities.)
- Restrictions in high and super-high sectors. Restrictions in low-altitude sectors, especially those adjoining Approach Control areas are not candidates since aircraft have to be descended for landing and sequencing for orderly arrival into the airport.
- Arrival restrictions. They are better candidates than departure restrictions. Internal departure restrictions frequently have little impact on departing aircraft. Regional jets, especially in warm weather, do not reach the departure altitude restriction at the time the aircraft crosses the restriction boundary.

The procedures and benefits teams utilized the output of the CAASD Analysis of Restrictions Tool (ART) to help identify candidates for restriction relaxation. The ART software was run for various days on which URET was active. The output lists all the restrictions in the facility, all the traffic subject to each restriction for the time that URET was functional, and the nautical miles (nmi) that on the average the aircraft were constrained to the restricted altitude.

Table 1 contains the fields in the analysis that are significant in identifying candidates for restriction removal. The Table is a subset of the complete list of restrictions for ZID on the specified day. Each of these restrictions meets the criteria set down by the teams as possible relaxation candidates. The restriction describes the location where aircraft must be at or below the crossing altitude. Each of the fields in Table 1 is described below.

- Restriction ID: Internal tracking number used to identify, sort, and refer to each restriction.
- Restriction Description: This field provides the arrival airport, boundary crossing definition, and the altitude to cross at or below.
- Number of Flights: This field specifies the number of flights that were subject to the restriction during the analysis period. Other aircraft may have met the criteria but were below the altitude.
- Average Passing Length: This field represents the average distance in nmi that the flights were in level flight at the restriction altitude.

Restriction ID	Restriction Description	Number of Flights	Average Passing Length	Cost of Restriction in Gallons per day
A.01	BNA_A_80/81_290	8	66	90
A.17.1	CVG_A_87/23_VIA_BOWRR_240	50	23.8	440
A.23	CVG_A_84/83_VIA_DRESR_240	57	31.1	510
A.25	CVG_A_80/35_VIA_JEANE_240	44	24.7	390
A.26	CVG_A_81/82_240	67	16	547
A.36	IND_A_84/82_310	9	39.2	84
A.37	IND_A_87/88_310	5	20.3	15
A.73	CMH_A_86/85_290	6	50	86
C25	SDF_A_ZME/19_SWEWO_110	7	16.4	114

Table 1. Sample set of ZID Altitude Restrictions from 18 November 1999 10-hour period

CAASD analyzed the traffic subject to the restrictions in Table 1 and identified aircraft type and cost penalty per restriction. The aircraft type data came from the data collection capability of the URET prototype. The cost penalty came from figures provided by airlines on fuel burn for aircraft type at various altitudes. Estimates of the fuel burn penalty were obtained for B737, B727, B757, B767, MD80, and Canadair regional jet. These are the most flown aircraft types within ZID airspace. From the information from the ART analysis and the fuel burn penalty data, the cost of each restriction in excess fuel used per day was estimated. Table 1 also contains the penalty of each restriction by the per day cost in gallons.

The teams at each site began meeting to plan restriction relaxation evaluations in October 1999. The evaluations undertaken as a result of this effort are described in the following sections.

Second Evaluation: 29-30 December 1999

On 29 December, the restriction A.36, that requires Indianapolis Terminal arrivals to cross the sector 84 to sector 82 boundary at FL310 or below, was lifted from 8:00 am to 11:30 am local time. The period from 8:00 am to 10:00 am was extremely busy in all participating sectors. Controllers managed traffic tactically; they had little opportunity for strategic planning in the first two hours of the restriction removal evaluation. The workload for the receiving sector controller in the super-high sector with the restriction removed was dramatically increased during the busy period.

Ten Indianapolis arrivals entered sector 84 during the evaluation. Six aircraft met the criteria for evaluation of the altitude restriction. Of these, two aircraft were descended for traffic considerations to the restricted altitude of FL310 during the busy period. Four aircraft stayed at altitude, above FL310, crossing the 84/82 sector boundary. Table 2 lists the flights that stayed at altitude and the fuel savings estimate.

The initial evaluation by the team was that until the center controllers move to a more strategic operation there was no real benefit in lifting this particular restriction during busy periods. However, when there is not heavy traffic, restriction removal was extremely beneficial. Traffic moved through both sectors at altitude for substantial distances with no problems encountered.

On 30 December the restriction A.01, that requires Nashville Terminal arrivals to cross the sector 80 to 81 boundary at FL290 or below, was lifted. Four Nashville arrivals entered sector 80 during the time that the test was conducted. One was descended to FL290 at the request of the receiving controller in sector 81. Two were at a lower altitude than the restriction. One aircraft remained at altitude longer, not descending to FL290 (see Table 2).

The procedures and benefits team determined that strategic planning in this instance was properly carried out and that most of the aircraft, had they been at altitude, would have remained at altitude for an appreciable period. It was agreed that this particular crossing restriction is a perfect candidate for extended testing and possible elimination. This restriction is affected by the Memphis operation; the ZID Team suggested that the removal of the restriction could, possibly, extend into ZME airspace.

Restriction Number	Number of Flights	Aircraft Type	Crossing Altitude	Remain at Altitude (nmi)	Estimate of Fuel Savings (Gallons)
A.01	1	B727	FL350	73	20.4
A.36	4	MD80	FL350	70	13
		C525	FL390	72	13.5
		B737	FL350	70	13
		A310	FL350	25	4.5

Table 2. Example: Impact of ZID Restriction Removal Test

Third Evaluation: 24-25 February 2000 at ZID

A third relaxation evaluation took place at ZID on February 24 and 25. On February 24 and 25, the restriction A.37, that requires Indianapolis Terminal arrivals to cross the sector 87 to 88 boundary at FL310 or below, was relaxed for several hours on each day. 18 aircraft were subject to the restriction. Of these 18 flights, only 11 saved fuel by staying at a higher altitude. The estimate of fuel savings for all 18 flights is 144 gallons.

On February 24, the restriction A.73, that requires Columbus Terminal arrivals to cross the sector 85 to 86 boundary at FL290 or below, was relaxed for several hours. 10 aircraft were subject to the restriction. All of these flights were kept at a higher altitude. The estimate of fuel savings for all 10 flights is 70 gallons.

A summary of each restriction evaluation is shown in Table 3. The fuel savings are the average savings per flight. The savings for restriction A.37 was averaged over all 18 flights even though 7 of the flights saved no fuel.

Further estimates were made concerning the possible savings from removing restrictions A.37 and A.73 permanently. Based on the traffic levels estimated from the CAASD ART analysis and site estimates, these flights represent about 40% of the daily traffic over the two restrictions. The average fuel saved per restriction per day during the evaluation was 80 gallons. This extrapolates to 400 gallons saved per day and 144,000 gallons saved for the entire year if just these two restrictions can be removed.

	Facility		RESTRICTIONS		IMPACT		
Date	**ZID**	**ZME**	**Restriction Description**	**Evaluation Duration**	**Number of Aircraft**	**Average longer distance at altitude per a/c, miles**	**Average Fuel Saved per aircraft, Gallons**
5/27/99	X	X	FL200 or below for Nashville arrivals	10:00am – 12:00pm	9	38.7	15
12/29/99	X		FL310 or below Indianapolis arrivals	8:00 am – 11:30am	4	59	11
12/30/99	X		FL290 or below for Nashville arrivals	8:00am – 10:00am	1	73	20.4
2/24 – 2/25/00	X		FL310 or below Indianapolis arrivals	8:00am – 12:00pm	18	57	8
2/25/00	X		FL290 or below for Columbus arrivals	8:00am – 12:00pm	10	54	7

Table 3. Summary of Restriction Relaxation Evaluations

Future Evaluations

The Memphis procedures and benefits team has examined all of ZMEs internal arrival restrictions. Five Nashville arrival restrictions are candidates for relaxation based on the criteria mentioned above. ZME intends to lift all five of these restrictions for a 30-day period starting in mid-March 2000 and then evaluate the results. ZME will also relax three Louisville arrival restrictions starting April 1, 2000. ZID intends to evaluate two additional restrictions starting in April for fourteen days: one for Indianapolis arrivals and one for Louisville arrivals.

The procedures and benefits teams at both sites will continue to relax altitude restrictions for the foreseeable future. ZID has about 70 restrictions that meet the criteria for relaxation and they will continue to review and evaluate. ZME and ZID will also start to discuss relaxing restrictions between facilities. CAASD will continue to support both facilities in their efforts through analysis of traffic and continuing to report on the potential user savings.

The airlines are a key player in this restriction relaxation effort. A clear understanding from the airline perspective as to the impact of particular restrictions needed. An effort was initiated in January 2000 to communicate with the airlines to determine the “high impact” restrictions affecting their aircraft traversing ZID and ZME. These data in conjunction with

the site procedure and benefit teams will drive the sequence of restriction relaxation evaluations.

4 Conclusion

The relaxation of selected restrictions during some parts of the day is enabled by the use of the more accurate URET information to support strategic planning (as compared with non-URET operations) and well defined procedures. Widespread use of the tool in support of strategic planning will enable restriction relaxation and be a step toward free flight. The resulting benefits of staying at altitude longer will be direct fuel savings to the aircraft operator. More evaluations in using this tool to relax restrictions is required before applying the tool for this purpose on a standard use basis. Continued evaluations will bound the problem as to how much relaxation may be available through use of the conflict probe tool. The future of relaxing restrictions is bright, but it must be carefully managed.

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