Nearing Completion - The APM at Washington Dulles International Airport

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ABSTRACT

Since its opening in 1962, Washington Dulles International Airport (IAD) has used a large fleet of mobile lounges to move passengers between the Terminal and aircraft, and in recent years, between the Terminal and midfield concourses. These lounges share the apron with aircraft, baggage tugs, and other apron vehicles. However, continued development of the airport to meet projections for both passenger and aircraft operations will exceed the capacity of this surface conveyance system. IAD has reached the point where an alternative passenger conveyance system is required.

In 2000, the Metropolitan Washington Airports Authority approved the Dulles Development (D2) program to provide IAD the facilities it would require to keep pace with the growth in air service and traveling demands of the Washington region. One of the key projects in the Dulles Development program is the planning, design, and construction activities for a new Automated People Mover (APM) system; also referred to as the "AeroTrain."

Scheduled to open in 2009, the AeroTrain subway system will take passengers between the Main Terminal and the midfield Concourses in a tunnel system free from all apron traffic. The Aero Train system is a fully automated transit system comparable in technology and complexity of construction to urban rapid transit systems.

The initial phase of the AeroTrain will include nearly 8 km (5 miles) of underground guideway, four stations, an offline maintenance facility positioned for future expansion, and a fleet of 29 cars.

This paper provides an overview of the AeroTrain and how it integrates with the airport-wide D2 program. The methods of procurement, division of work, master schedule, and construction progress will be discussed.

DULLES DEVELOPMENT PROGRAM

The Metropolitan Washington Airports Authority (MWAA) operates and maintains Ronald Reagan Washington National Airport (DCA) and Washington Dulles

International Airport (IAD). In early 2000 with IAD handling 20 million annual passengers, MWAA's Office of Engineering began the process of defining a major, 10-year/$3.4 billion, capital construction program for IAD. The program is called the "Dulles Development Program" or "D2 Program." A major focus of the D2 program is the construction of the initial portion of an underground automated people mover system (AeroTrain) to connect the midfield concourses with the Main Terminal. The AeroTrain will largely replace the existing mobile lounge system that operates on the apron. Aside from the age of the existing mobile lounge fleet - some vehicles date to the airport's opening in 1962 - the use of this surface conveyance system severely limits the overall expansion potential of the airport and provides lengthy travel times for passengers to reach their gates. The AeroTrain will alleviate these challenges. Beyond the D2 program, the master plan for IAD calls for the replacement of one of the existing concourses, the construction of two additional concourses, a second landside terminal on the south side of the terminal area, and other improvements. This would represent a significant expansion of the airport's capacity to efficiently process passengers and will take place over several decades. Ultimately, IAD will have the capacity to handle 60 million annual passengers. The AeroTrain is an essential element in realizing this growth potential.

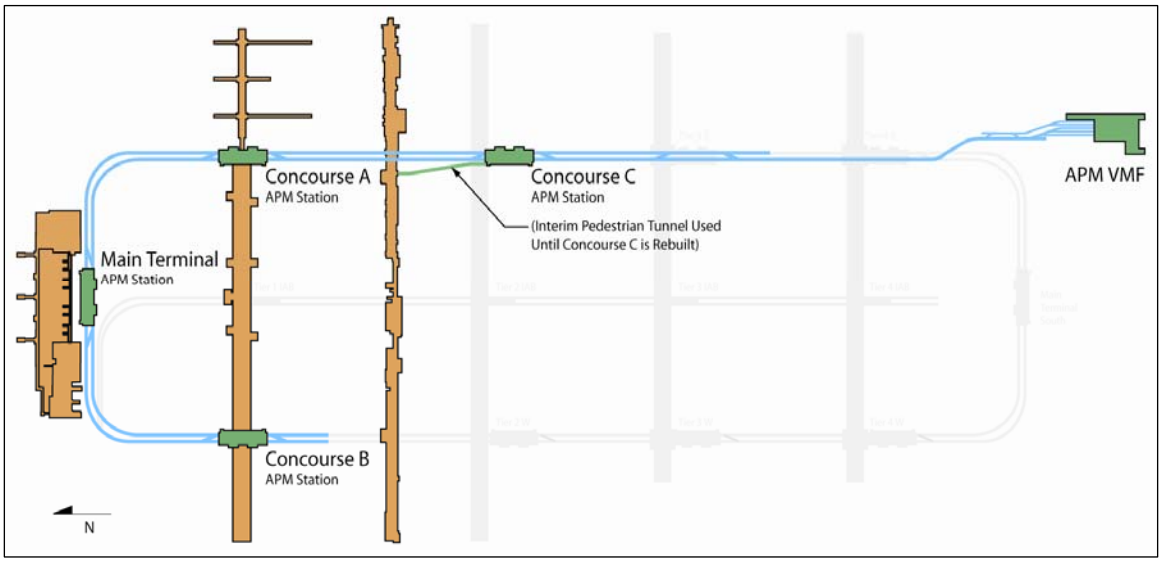
Mobile Lounges

THE AEROTRAIN

The initial phase of the AeroTrain will provide passenger service between four operational stations (Main Terminal and three concourse stations), the structural shell for a fourth concourse station, and a maintenance and control facility. The 8 km (5 miles) of guideway is configured in a "U" shaped dual-lane alignment serving all domestic passengers and departing international passengers. Crossovers provide for routine and failure management operations and pinched-loop operation with bidirectional trains crossing over before the end stations. The initial phase has 29 vehicles that operate in three-car trains at 115-second headways that provide a capacity of 6,755 passengers per hour per direction (pphpd). DC power is provided to the system from three traction power substations in a redundant configuration typical for rapid transit systems.

The total design and construction cost for the AeroTrain, including the stations, tunnels, maintenance and control facility, vehicles, guideway and power systems is $1.3 billion. Of that total, the program cost of the APM system elements such as the vehicles, train control, guideway surface, guidance and power rails, traction power systems, central

control facilities (a primary and alternate control room), 128 station platform doors, and fit-out of the maintenance and control facility is $193 million, or 16 percent. The fixed facility costs are by far the greater costs of the overall AeroTrain program.



AeroTrain Alignment and Stations (Initial Phase)

PROCUREMENT APPROACH

MWAA procured the fixed facility components of the AeroTrain using the traditional Design-Bid-Build approach that has been used successfully on prior capital construction programs at IAD. This procurement approach was also considered for the APM system of the AeroTrain. However, due to the proprietary nature of driverless transit systems, it was determined to procure the APM system using a Design Build Operate Maintain (DBOM) approach that included a five-year period of operation and maintenance. Design-Build and DBOM approaches have been used successfully on several airport and urban transit projects.

Given the size of the AeroTrain system and necessity to maintain airside operations, MWAA divided the program into the following major design and construction packages:

- APM Operating System;
- APM Tunnels;
- Main Terminal APM Station;
- Concourses A and B APM Stations;
- Concourse C APM Station; and,
- APM Vehicle Maintenance Facility.

MWAA's Office of Engineering advertised for a General Engineering Consultant (GEC) and APM Consultant to supplement its own staff in managing the D2 program and

AeroTrain project.

Parsons Management Consultants, a joint venture with Parsons Transportation Group, Parsons Brinkerhoff Construction Services, Daniel, Mann, Johnson & Mendenhall, and Delon Hampton & Associates, has been providing GEC and Program Management services to MWAA since 1989.

MWAA's Design department retained Lea+Elliott, Inc. as the APM Consultant in 2000. Initial work consisted of developing the overall APM system schedule from project definition through procurement, design and implementation; defining the division of work between the APM system and fixed facilities; developing the APM system procurement documents; and establishing the preliminary criteria to be followed in the initial design of the fixed facilities that interface with the APM system.

The design of the major fixed facilities (stations, tunnels and vehicle maintenance facility) started prior to the final selection of the APM system itself. In order for the fixed facility designs to progress, the various designers were given design criteria based on a combination of generic APM system parameters and representing the most restrictive train technologies possible. This allowed the designs for the fixed facilities to begin in 2000 and 2001 even though the final selection of the APM system was not until March 2003. In fact, the award of the first major construction contract was for the Main Terminal station in 2002. Design of the APM train system progressed from 2003 until 2005 while all of the construction of the fixed facilities was underway. When the APM construction started in 2006, it was necessary to adjust the APM construction phasing to match the progress on the fixed facilities and the availability of tunnel sections and equipment rooms in the stations and vehicle maintenance facility. Throughout the entire design and construction process, adjustments have been made to the phasing of individual contracts to maintain the overall schedule for the opening of the APM system in July 2009.

The attached exhibits shows the interrelationship of the major construction activities over the past 2 years.

APM System

Following a competitive procurement process, MWAA awarded Sumitomo Corporation of America (SCOA) the design and construction portion of the DBOM APM operating system contract in March. Other major members of the project team with SCOA include: Mitsubishi Heavy Industries, LTD. as the system integrator and vehicle manufacturer; Thales (formerly Alcatel Transport Automation Solutions) as the automatic train control supplier; and L.K. Comstock and Company Inc. as subsystem designers and site construction manager.

The APM system contracts include the design and manufacture or construction of 29 “Crystal Mover” vehicles, running and guidance surfaces, emergency walkways, automatic train control systems, wireway for communications, electrical power, traction control, and station platform doors and related communication equipment.

Crystal Mover APM Vehicle by MHI

Many of the Aero Train subsystems, including train control, traction power, propulsion, and communications, are the same as those used on modern urban transit systems. Other design features, such as automatic station doors and system-wide monitoring of equipment condition, exceed the feature usually found in rail transit systems.

APM Tunnels

In 1999, MWAA selected HNTB Corporation, in association with Lea+Elliott, Inc., to complete the planning of the D2 program, develop ridership models, and finalize the APM tunnel alignment. A few years later, MWAA selected HNTB Corporation, in association with Hatch Mott MacDonald, as the architects and engineers to produce the APM Tunnel construction documents.

Cut-and-Cover construction was selected for the tunnel segments that are adjacent to existing facilities and at the “green field” areas where access did not disrupt airfield operations. The rock excavation averaged a depth of 15 meters (50 ft). Steel rock bolts and shotcrete facing provide the excavation support to the in-situ materials. For tunnel sections under taxiways and concourses, the tunnels were mined using NATM or TBM methods. For the NATM method of construction, the tunnel was mined utilizing more conventional excavation equipment that dug through the tunnel face in one to two meter (3 to 5 ft) ‘bites’. Shotcrete was immediately applied to the exposed tunnel walls to provide support. The TBM tunnel segments on the east side are seven meters (23 ft) in diameter and used two custom machines, known as moles, to bore through solid rock, utilizing multiple cutting wheels mounted into a face shield. Precast concrete wall lining segments were mechanically put into place by the mole as it continued to move forward and the tunnel invert was poured in a later step

The tunnel design was divided into two separate packages that were advertised in 2003:

- The East package for the APM tunnels extending east of the Main Terminal and south through the Concourse A and C stations, the future locations of Tiers 3 and 4, and to the APM Maintenance and Storage Facility.
- The West package for the APM tunnels extending west of the Main Terminal and south to the Concourse B station.

The tunnel packages also include ventilation, drainage, fire protection, security, and emergency communications designed to NFPA-130 and other prevailing codes.

MWAA awarded Atkinson/Clark/Shea, a Joint Venture, the East APM Tunnels construction contract in. The project includes 1730 meters (5,677 ft) of box tunnels constructed by traditional cut and cover techniques, 1320 meters (4,330 ft) of tunnels using the Tunnel Boring Machine (TBM) method, and 251 meters (825 ft) using the New Austrian Tunneling Method (NATM). Additional work includes 324 meters (1062 ft) of open-cut construction of the APM Station at Concourse A and a shell for a future APM station at location for Tier 3E.

MWAA awarded Clark/Shea the West APM Tunnels construction contract in 2004. The project includes 573 meters (1,881 ft) of tunnels constructed by NATM, 679 meters (2,229 ft) of box tunnels constructed by cut and cover techniques, and 183 meters (600 ft) of excavation for the Concourse B APM station.

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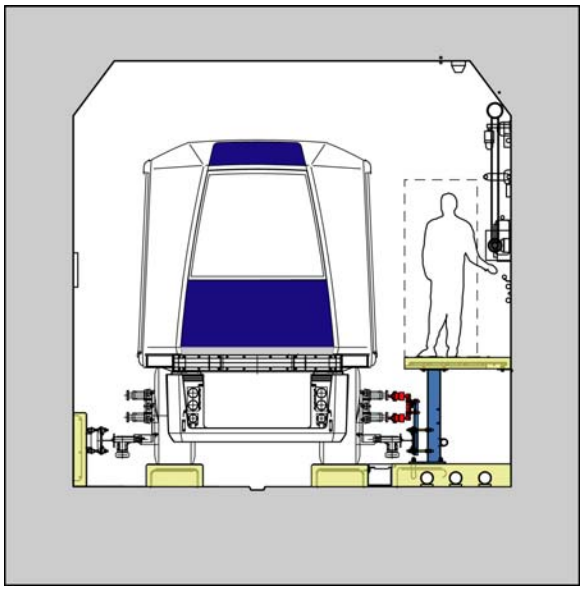
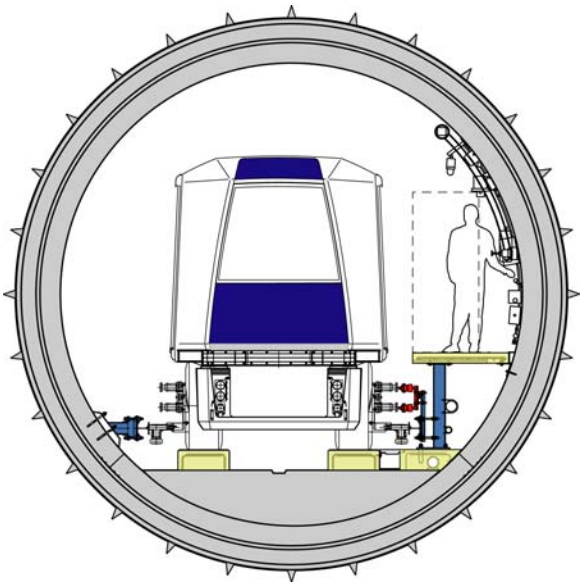


Cut-and-Cover APM Tunnel by HNTB
(APM Fitout by SCOA)



Mined APM Tunnel by HNTB
(APM Fitout by SCOA)

APM Stations

The initial phase of the APM system includes four stations: the Main Terminal Station designed by Skidmore, Owings & Merrill, the Concourses A and B stations designed by

Hellmuth, Obata, + Kassabaum, Inc., and the Concourse C station designed by Kohn Pedersen Fox Associates. The basic design for all the stations is a three platform (side-center-side) configuration where passengers enter the train from the center platform and exit the train to the side platform to avoid congestion at the doorways. The stations have platform-edge doors that operate in synchronization with vehicle doors. A glass enclosure around the train to eliminate passenger exposure to the guideway and provides a level of safety greater than that of most urban transit systems. While the finishes in each station vary, the passenger flows and locations of vertical circulation elements are similar.

Main Terminal APM Station

In 1989, MWAA selected Skidmore, Owings & Merrill (SOM) to design a series of projects to expand the Main Terminal. The last project included the Main Terminal APM Station, security mezzanine, and mobile lounge docks.

Main Terminal APM Station by SOM

The APM station is located on the airside of the existing Main Terminal. To maintain mobile lounge, baggage, and TSA screening operations, it was necessary to construct the APM station in several phases. The initial phase included the construction of temporary mobile lounge docks, holding area, and a connecting pedestrian walkway that are clear of the station construction activities. This allowed MWAA to remove mobile lounge operations from the west side of the Main Terminal so the western half of the APM station could be excavated and constructed in a subsequent phase. A parallel activity was the construction of a temporary TSA screening area (21 lanes) clear of station

construction activities. The new screening area opened in 2006 and enabled MWAA to start the remaining station excavation and construction on the east side of the Main Terminal. Permanent mobile lounge docks were constructed on the west and are now operational. MWAA awarded Turner Construction the Main Terminal APM station construction contract in 2002.

Concourses A and B APM Stations

In 2001, MWAA selected Hellmuth, Obata, + Kassabaum, Inc. (HOK) to design Concourses A and B APM Stations and the West Concourse B Terminal Expansion.

The Concourse A APM station is a center platform station designed to tie into the existing buildings (Concourses A and B) without significant disruption. Once complete, the station will allow mobile lounge service beneath the existing bridge connecting the two concourses. Construction of the station's side platforms are deferred until a later phase.

The construction of the Concourse A APM station was packaged with the East APM Tunnels and awarded to Atkinson/Clark/Shea, a Joint Venture in 2004. The factor behind this decision was the flanking TBM construction and the need to drive the TBM moles through the station.

The Concourse B APM Station includes the construction of a three-story concourse extension consisting of 12 additional gates (six for wide body aircraft), apron level support space, and a basement.

MWAA awarded a contract to Balfour Beatty for the construction of the Concourse B APM Station and 12-gate terminal expansion contract in September 2005. The work includes interfaces with NATM and cut-and-cover tunnels constructed by others as well as coordination with the installation of APM enclosures and the APM system contract.

Concourse A and B APM Stations by HOK

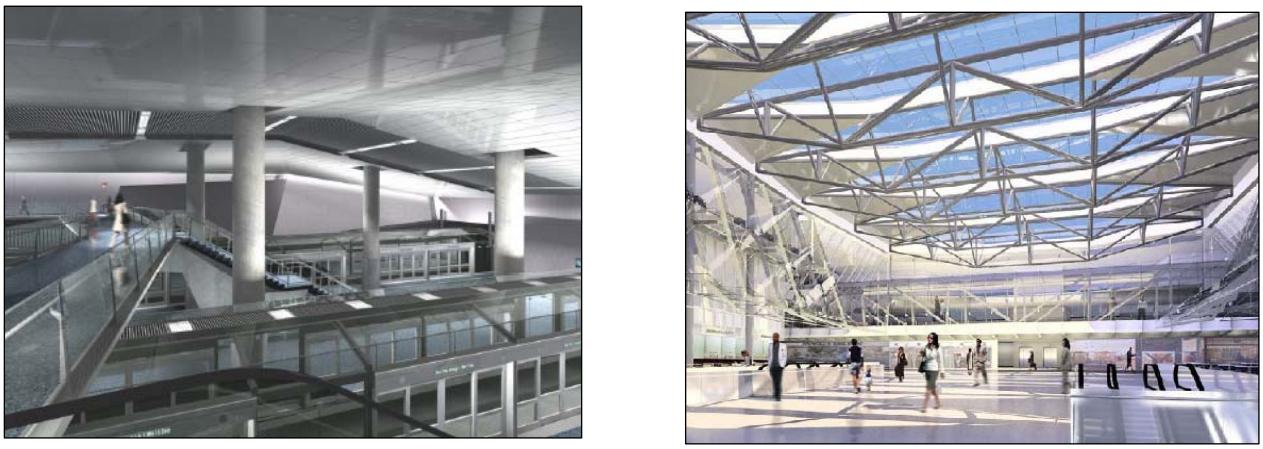
Concourse C APM Station

In 2001, MWAA selected Kohn Pedersen Fox Associates (KPF) to design the Tier 2 Midfield Concourse and the Concourse C APM station.

The new concourse will replace the existing Concourse C/D and will be a length of 1,230 meters (4,035 ft), have 44 domestic and international gates, and accommodate 22 wide body aircraft including the Airbus A380 and Boeing 747-800. The new concourse will be approximately twice the size of the existing concourse and offer additional space for concessions and other passenger amenities, airline clubs, a substantially larger Federal Inspection Service facility for process transferring Star Alliance international travelers.

Although the final design and construction of the concourse has been deferred until a later phase in the master plan, the APM station at the eastern quarter point is being built. This station will link passengers to Concourses A and B and the Main Terminal and serve as the APM system's eastern terminus. An interim pedestrian tunnel connects the station to the existing Concourse C and mobile lounges will continue to serve Concourse D and international arriving (destination) passengers and some international departures.

MWAA awarded Facchina Construction Company, Inc. the construction of the Concourse C APM station contract in 2002. The project includes construction and fitout of the APM station and an at-grade temporary central plant facility. The work includes interfaces with TBM and cut and cover tunnels constructed by others as well as coordination with the installation of APM Enclosures and the APM System Contract.

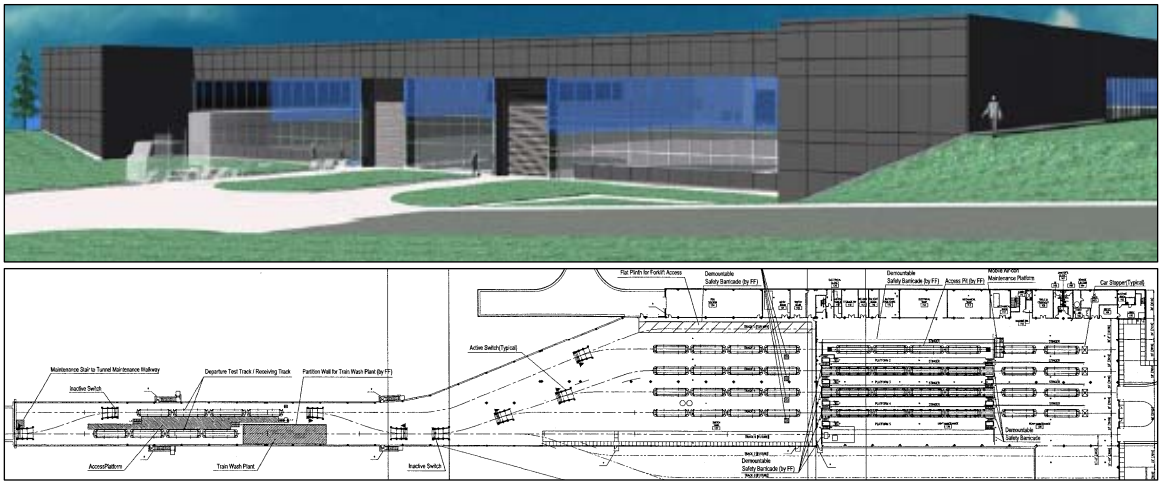


Concourse C APM Station by KPF

APM Vehicle Maintenance Facility

In 2001, MWAA selected HNTB Corporation to design the APM Vehicle Maintenance Facility (VMF). The at-grade VMF includes provisions for five tracks of light and heavy maintenance bays, switch yard, offices, departure test track, shops, storage, and the Central Control Facility for APM operations. Although designed to accommodate a system of 63 vehicles, the VMF may be expanded by four additional tracks of light and heavy maintenance bays in the future.

MWAA awarded Turner Construction for the construction of the APM Vehicle Maintenance Facility contract in July 2004.



APM Vehicle Maintenance Facility by HNTB

SCHEDULE

The attached schedule depicts the remaining fixed facility milestones and corresponding access to the APM system contractor. Continuous adjustments to the schedule are being made to ensure that both short - and long-term goals are achieved.

CONSTRUCTION PROGRESS

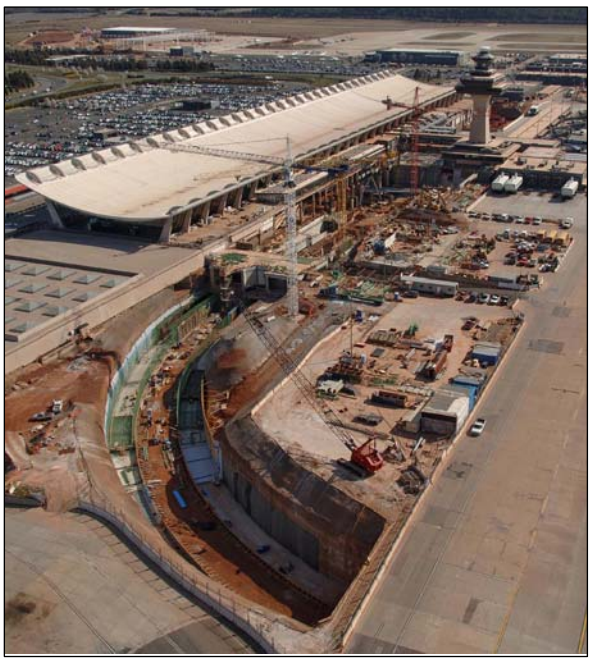
The majority of the civil work on the east tunnels is complete and has been turned over to the APM contractor who is currently installing the plinths and train control systems. Joint access continues with the tunnel and APM system contractors while tunnel MEP systems are installed. The civil work on the west tunnels is scheduled to be completed by early 2007 and will then be turned over to the APM contractor. The civil work for the majority of the station basement and platform elevations is complete with civil work continuing on the mezzanine elevation and above. The VMF is complete and has been turned over to the APM contactor whose fitout work is in progress.

SCOA completed the vehicle qualification testing in December 2006 and the first four vehicles are scheduled to arrive at IAD in April 2007. The balance of vehicles will be shipped in two batches by the end of 2007.

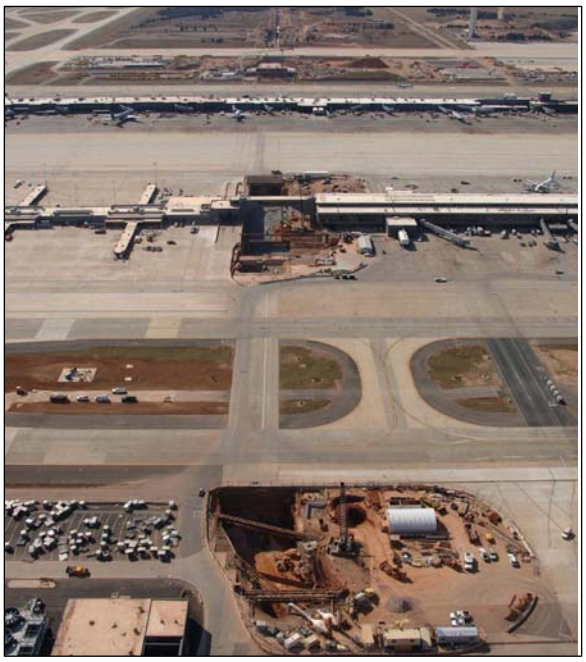
Capital construction programs the size of the AeroTrain, are not feasible without a significant amount of effort by all stakeholders. Contractor man-hours reported through 2006 are:

- APM System: 83,000 man-hours
- Main Terminal and Concourses B and C APM Stations: 2,400,000 man-hours
- East and West Tunnels and Concourse A APM Station: 2,100,000 man-hours

- Vehicle Maintenance Facility: 300,000 man-hours



Cut and Cover Tunnel and Main Terminal Station



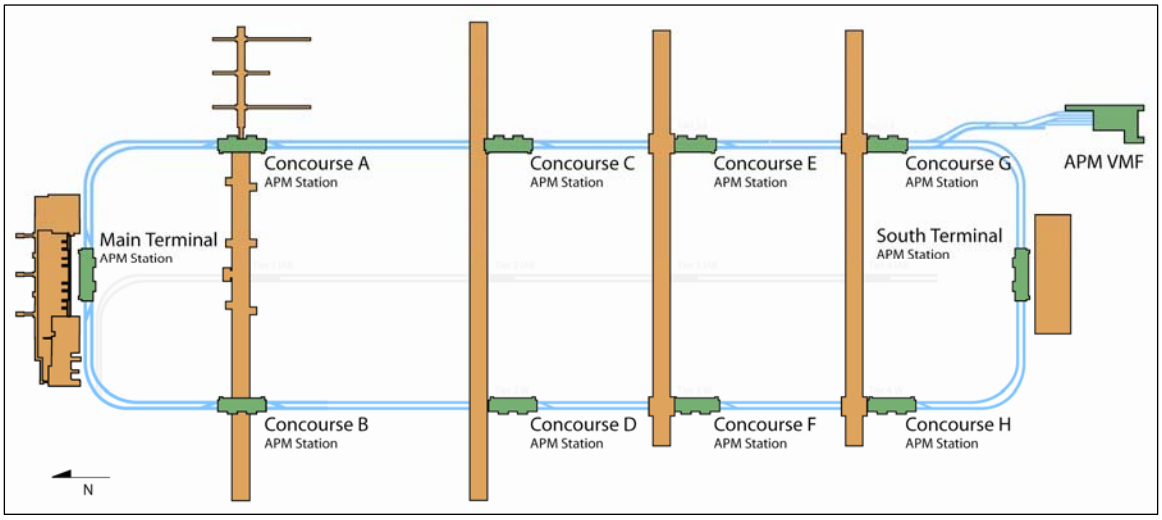
TBM Portals and Concourse A Station

BEYOND PHASE 1

Over its 45 year history, IAD has become one of the nation's largest airports. With this evolution, the airport has grown and expanded to meet the continuing demand for additional facilities.

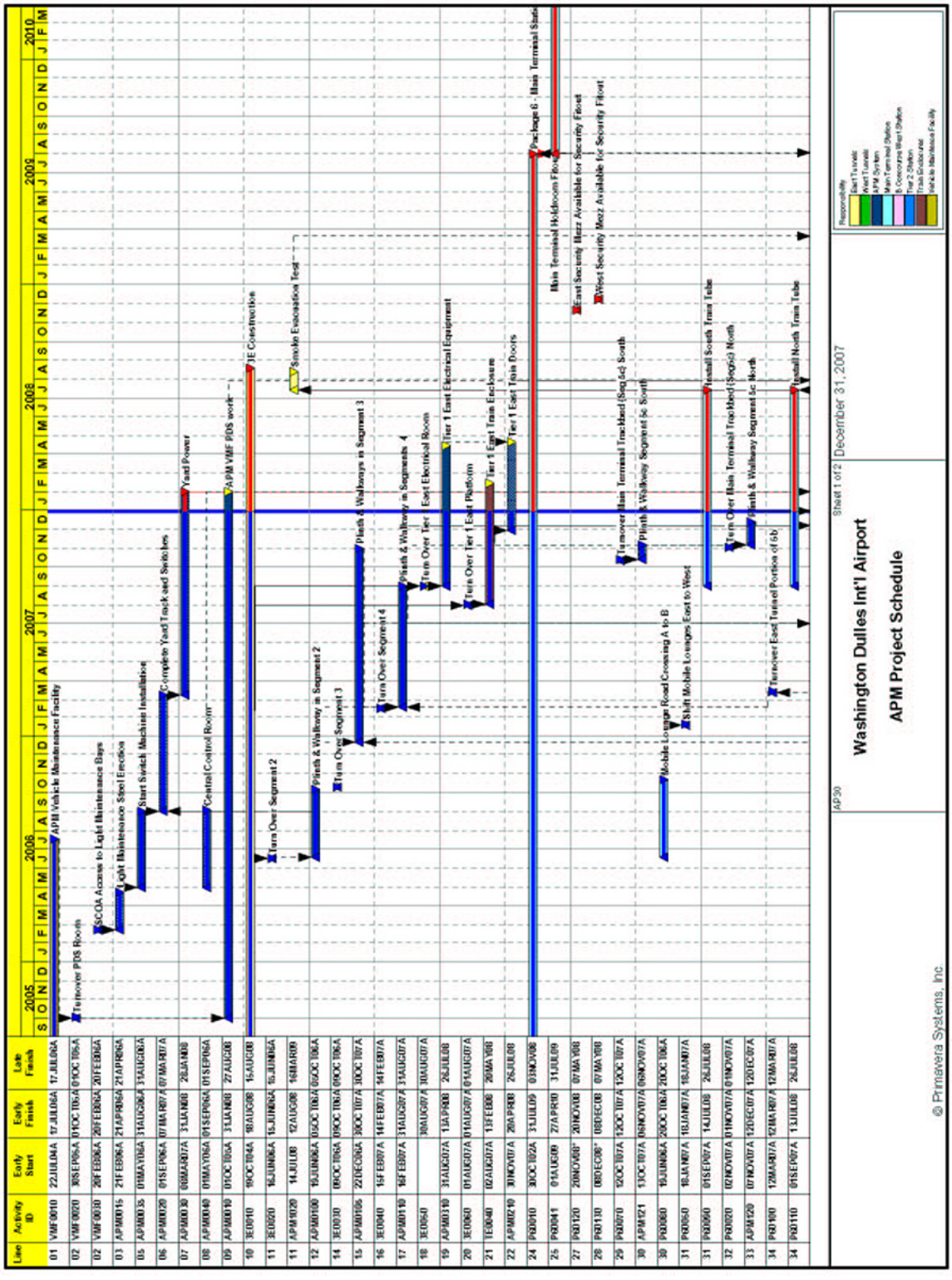
MWAA has taken the necessary steps to maximize the future capacity of the AeroTrain system so it will not limit the physical potential of IAD and the economic potential of the community. While the initial phase of the AeroTrain system will provide the basic passenger conveyance system for the existing terminal and concourses, as future tiers are added and a second landside terminal is developed, the AeroTrain system will be expanded incrementally. The AeroTrain system is envisioned as ultimately having eight concourse stations, two landside terminal stations, 16 km (10 miles) of track, and 58 vehicles. The ultimate capacity of the system in a four-car train mode with 115 second headways is 8,950 pphpd.

Washington Dulles is in a constant state of evolution and improvement. The challenge for the Washington Metropolitan Airports Authority is to continue to keep pace with growth in air service and meet the future traveling needs of the Washington region. Planning, design, and construction of facilities at IAD has always been characterized by a philosophy of protecting for future activity levels that will be larger and different in nature than what is occurring today.



AeroTrain Alignment and Stations (Ultimate Phase)

Exhibit 1 – APM and Fixed Facility Integrated Schedule



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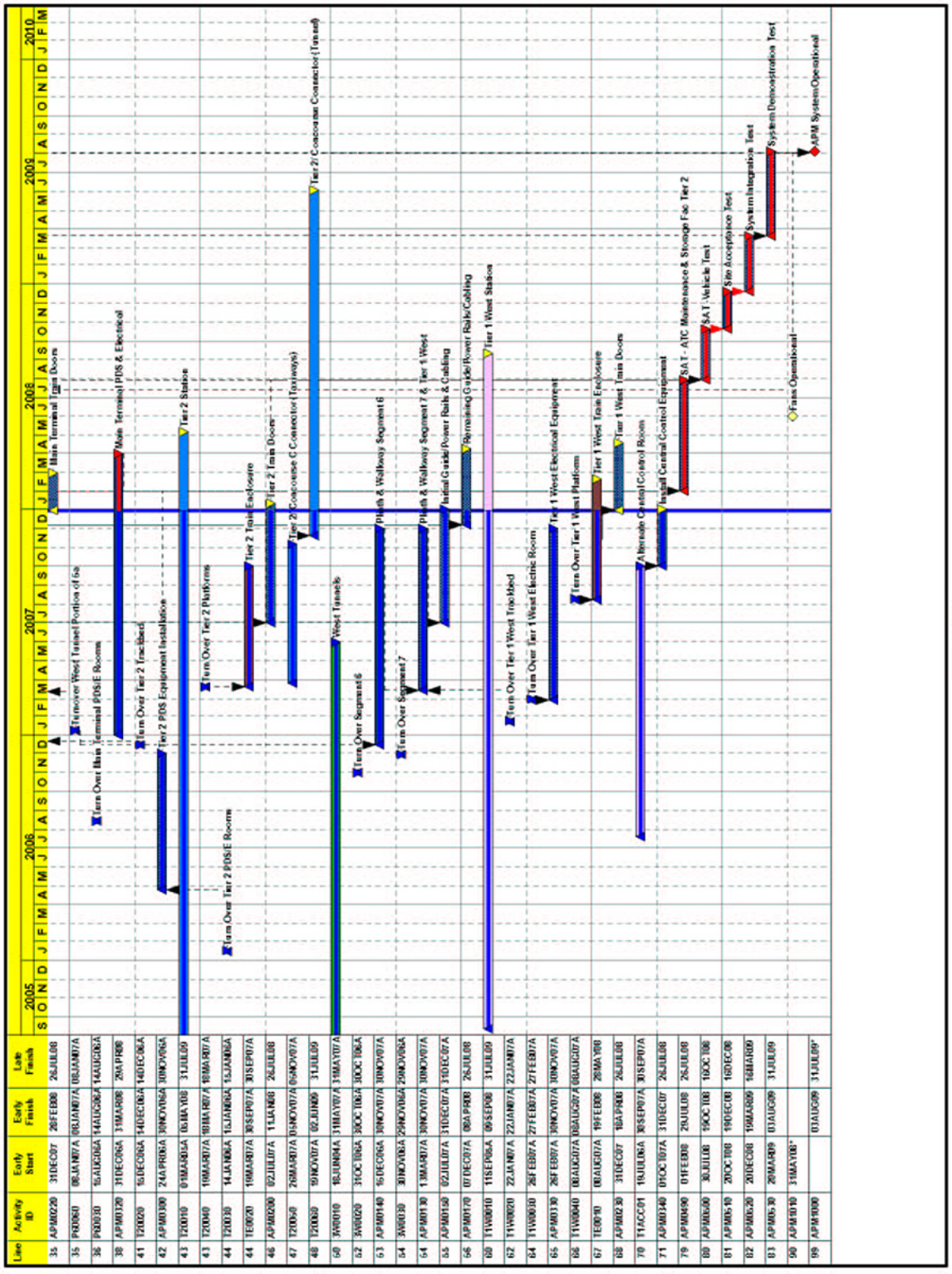

Exhibit 2 – Design/Construction Matrix

APM and Fixed Facility Design/Construction Matrix
($ millions)

Total Design $148 m / Total Constr. $1,043 m	SOM / $42 m	HOK / $20 m		KPF / $21 m			HNTB-HMM / $46 m			SCOA / $19 m			
										MHI	Thales	Burns	
	Main Terminal Station, Security Mezzanines and Enclosures	Concourse A Station	Concourse B Station	Concourse C Station	Concourse C Pedestrian Tunnel	Concourse Enclosures	East Tunnels	West Tunnels	Vehicle Maintenance Facility	Vehicles	Train Control	Guideway	Electric
Turner / $333 m	P						C	C	P	C			
ACS / $260 m	C	P				C	P		C	C			
CS / $75 m	C		C					P		C			
Balfor Beatty / $55 m			P			C		C		C			
Clark / $ 29 m				C	P								
Facchina / $109 m				P		C	C			C			
GW / $ 8 m		C	C	C		P				C			
SCOA / $174 m MHI	C	C	C	C		C	C	C	C	P	C	C	C
Thales									C	C	P		
LKC		C	C	C						C	C	P	P
RailWorks										C		C	
Powell										C			C

Legend: SOM - Skidmore, Owiings & Merrill
HOK - Hellmuth, Obata + Kassabaum
KPF - Kohn Pederson Fox Associates
HNTB-HMM - HNTB and Hatch Mott MacDonald
SCOA - Sumitomo Corp. of America
MHI - Mitsubishi Heavy Industries
ACS - Atkinson/Clark/Shea Joint Venture
CS - Clark/Shea Joint Venture
GW - Grunley Walsh
LKC - L K Comstock

P = Primary design/construction responsibility

C = Coordination/integration responsibility