DART Super Light Rail Vehicles Low Floor Center Section the Final "Successful" Chapter

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BACKGROUND:

- Dallas Area Rapid Transit (DART) opened service in June 1996 with 22 miles of track and 40 Light Rail Vehicles (LRV)

- In December 2002, DART opened the Phase I expansion which added 22 miles of track, doubling the size of the system, and increased the size of the fleet to 95 cars.

- Another 20 LRVs were added to the fleet in 1999 to improve service. This increased the size of the fleet to 115 cars.

- In 1999-2000 DART was in the early stages of planning and coordinating the Phase II expansion. This was not the standard expansion of extending a line to add one or two stations. The Phase II Build out added two complete new lines:
  - Green Line - from the northwest corner of the DART Service area, through the downtown area to the southeast corner of the service area

  - Orange Line - from the Green line just north of the downtown area going west and then angling north to end up with the terminal station for the line inside the Dallas Fort Worth International Airport (DFW).

  - Extension of the Blue line from Garland further east to Rowlett

  - Extension of the Red line from Ledbetter further South to Interstate -20

  - Overall, the Phase II Expansion adds approximately 44 miles of double track and doubles the size of the DART Light Rail Transit (LRT) System.
- As part of the Phase II expansion DART also wanted/needed to:

  - Improve the train control systems by including a wayside Cab Signal system as part of the new Green and Orange lines and installing Automatic Train Protection (ATP) on the LRVs. (Cab Signal was not installed on the existing Red and Blue Lines)

  - Improve management and scheduling of the overall LRT System by adding a GPS based Vehicle Business System (VBS) on the LRVs.

  - Increase the passenger capacity of the fleet.

  - Convert the overall system (both existing and new lines) to level boarding to improve passenger accessibility.

- Control costs and stay within a budget.

The Phase II Expansion is a significant undertaking requiring coordination with multiple municipalities and utility suppliers (power, water, gas, communications, etc.) in the service areas and major contracts for construction, systems and vehicles. The stories and sagas of the construction work and supply and installation of the systems equipment are covered in various other presentations and venues. The focus of the remainder of this paper is on the vehicles, the evolution of the prototype low floor center section or C-unit and the conversion of the C-unit into a routine production reality for DART's entire fleet of 115 vehicles.

VEHICLES

When DART started the Phase II expansion, the LRT system used 115, relatively new, "high floor" LRVs. The cars were manually operated following train control from a visual wayside signal system that had magnetic trip stops for enforcement at critical points along the line. The requirements for ADA compliance were satisfied with the use of wayside high blocks and manually operated trap and bridge mechanisms at the cab end doors of the LRVs. To meet the requirements and goals of the Phase II expansion DART had to:

- Increase the capacity (size) of the fleet
- Install ATP on all of the cars
- Install VBS on all of the cars
- Convert the overall LRT system, both the existing 44 miles and the new 44 mile Phase II Expansion, to level boarding configuration

For the vehicles the two normal courses of action to change and meet these kinds of requirements are:

1. Scrap/sell the existing cars and purchase an entire new fleet that meets the requirements
2. Purchase new cars with the required characteristics and operate a mixed fleet of old and new cars.

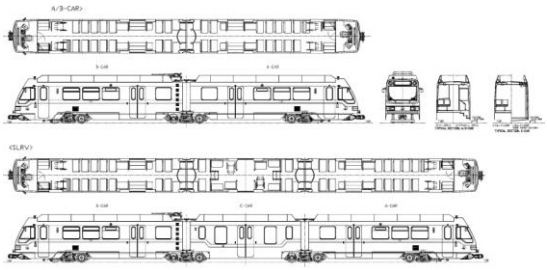
These courses of action have the significant drawbacks of either very high cost to purchase a whole new fleet or the significant inconvenience for material management, operations and maintenance to operate a "mixed" fleet of high floor and low floor cars

To address the drawbacks, a third course of action was developed, the concept of a low-floor, center unit (C-unit). This C-unit was intended to be inserted between the A-unit and B-unit of each of the 115 LRVs. This concept changed a standard 6 axle, single articulated LRV into an 8 axle, double articulated Super LRV (S-LRV) and achieved a number of the goals for the Phase II Expansion without any of the normal disadvantages, as follows:

- The passenger capacity for each car, and the overall fleet, was increased by approx 30%
- Direct "level boarding" into the C-unit was provided for all cars
- Problems associated with operating and scheduling a mixed fleet of high and low floor cars were eliminated
- Problems associated with maintaining a mixed fleet of cars were eliminated
- Problems with stocking inventories of spare part for a mixed fleet were eliminated.
- Over $50 million in savings or reduced costs were realized as compared to the other two courses of action for increasing capacity and converting to level boarding

PROTOTYPE C-UNIT

The concept of the C-unit was refined and developed into a preliminary design.



After a thorough review did not identify any pitfalls with the concept, DART and Kinkisharyo (car builder for the existing fleet of 115 LRVs) entered into an agreement to actually build a prototype C-unit, install it in a DART LRV, test it and then operate the prototype S-LRV with the C-unit installed, in actual revenue service.
This prototype project was successful. All of the performance and operational goals were achieved during the qualification testing phase:

- Acceleration - 2.34 MPHPS
- Braking - 3.0 MPHPS
- Operating speed - 65 MPH

After completing the dynamic testing, the prototype S-LRV was successfully operated in normal revenue service from August 2002 until June 2008, when the prototype C-unit was replaced with the production version of the C-unit. This extended prototype test under actual, revenue service, conditions confirmed and proved the design concept of the low floor center section. Additionally it demonstrated that the S-LRVs could be incrementally and seamlessly added into the revenue fleet to replace the LRVs with no impact to rail operations or passenger service.

CONVERSION OF LRVs INTO S-LRVs

With the operation of the S-LRV confirmed by the testing and long term operation in revenue service, DART was sufficiently confident enough with the S-LRV design to move forward and include the conversion of the LRT system to the level boarding configuration as part of the Phase II Expansion. Contracts were awarded for all of the new construction for the 44 miles of new lines, conversion of the maintenance shop and facilities to accommodate the longer S-LRVs, modification of the 44 existing stations to level boarding configuration and a contract to purchase 115 C-units to modify/convert the entire fleet of LRVs into S-LRVs. Included with the procurement of the 115 C-units was procurement of an ATP system and VBS to be installed on each car as part of the S-LRV conversion.

The DART C-unit conversion-modification project was both unique and challenging. The plan was to convert the entire fleet of cars to the S-LRV configuration without affecting the ongoing revenue service operation. Each car was removed from service and converted to an S-LRV; ATP and VBS were installed, testing was completed, the car was returned to service and another LRV was started into the conversion program. As with any new procurement from a foreign car builder, the manufacturing and initial preparation of the C-units and new trailer truck was done off shore at the Kinki Sharyo Ltd. main manufacturing facility in Osaka, Japan.

To comply with the Buy America requirements a final assembly site for the C-units and new trailer truck was established in Dallas, Texas.

The final step of delivering the new equipment to an agency, completing the dynamic testing and accepting the new car into service, was more

complicated than normal. An operating LRV had to be removed from revenue service and transferred to Kinkisharyo to install the C-unit and 4th truck, ATP system and VBS. After the installation and assembly work was completed, the car, now converted to an S-LRV, was returned to DART for dynamic testing and burn-in operation and was then released for revenue operation after acceptance. All of this had to be done without affecting normal revenue operation and completing the conversion of the entire fleet of 115 cars in time to support the opening of the new lines of the Phase II Expansion.

From DART's point of view, the most important consideration of the conversion process was to minimize the impact on the ability to meet the daily revenue service pullout requirements. That is, the number of cars that were out of service being converted into S-LRVs could not affect the ability of the Fleet Maintenance Department to perform normal running and preventative maintenance, meet the daily revenue service pull-out requirement and have a few spare train sets. After an in depth review and discussion it was determined that a maximum of eight cars could be released to the C-unit conversion program at any one time without affecting the overall revenue and maintenance operation.

To perform the SLRV conversion, add ATP, add VBS, test, run 1,000 miles of burn-in operation and stay within the 8-car limit was the focus and challenge of the project. Although the manufacturing and final assembly activities are significant and normally the primary parts of a new car procurement, in this case, these two major parts of the project effectively became support activities for the S-LRV conversion process. To meet this challenge of converting the cars without affecting revenue operation, a small, 5-position, assembly line was setup, partially inside the DART maintenance yard and partially on DART land immediately adjacent to the yard. By having this conversion facility inside and immediately adjacent to the DART yard with a direct rail connection the complication, time, risk and cost of transporting the LRVs off site and returning the completed S-LRVs back to DART was eliminated.

Overall, the process of converting an LRV into an S-LRV along with the installation of ATP and VBS, testing, burn-in operation and returning a completed S-LRV back to service takes seven weeks. The seven cars in the conversion process move to the next station/phase on Mondays of each week. The phases of the conversion are as follows:

1. Week #1, DART Shop and Station #1 inside the DART Maintenance Yard

    a. Delivery of an LRV into the conversion program and joint (DART and Kinkisharyo) inspection and documentation of the status and state of repair of the LRV that is entering the conversion process. This joint inspection occurs first thing on Monday mornings.

    b. Move the LRV to Station #1 by noon to start the actual work, (inside the DART maintenance yard)

    c. Modification of trucks for S-LRV configuration and installation of ATP equipment.

    d. Modification of under floor equipment for S-LRV configuration

    e. Modification of the operators' cabs in the A and B units and installation of the ATP and VBS equipment in the cabs.

    f. Installation of new wiring for the ATP and VBS equipment over the roof from the articulation area to the operator's cab in the A-unit and B-unit.

Over the weekend between Weeks #1 and #2 the LRV is moved from Station #1 to Station #2, which is outside but immediately adjacent to the maintenance yard

2. Week #2, Station #2 at a Kinkisharyo facility immediately adjacent to the Maintenance Yard.

a. Transport the C-unit and new trailer truck from the final assembly site to Station #2.

b. Disconnect and split the LRV into the separate A-unit and B-unit.

c. Insert the C-unit and new trailer truck and connect all three units, A, B and C, together as a complete vehicle.

d. Install the bellows in the two articulation areas.

e. Water test both articulation areas.

f. Button up the exterior of the articulation areas.

3. Week #3, Station #3 at Kinkisharyo facility adjacent to the Maintenance Yard.

   a. Install the electrical connections between the A and B units to the new C-unit

   b. Install the electrical connections from the new ATP and VBS equipment installed in the C-unit to the new wiring over the roof to the A and B cabs.

   c. Perform unpowered electrical testing.

   d. Power-up the car and start preliminary testing

4. Week #4, Station #4 at Kinkisharyo facility adjacent to the Maintenance Yard.

   a. Power-up testing of all new systems and equipment on the C-unit

   b. Power-up testing of the new ATP and VBS equipment in the A and B cabs.

   c. Power-up, static, testing and verification of the interfaces between the existing equipment/systems on the A and B units with the new equipment/systems on the C-unit and new trailer truck, including:

      i. Propulsion

      ii. Friction brakes

      iii. Door control

      iv. All train line functions from the A end cab though the C-unit to the B end cab

      v. All local car line functions between the A, B and C units

5. Week #5, Station #5, outside the building, at the Kinkisharyo facility adjacent to the Maintenance Yard

   a. Continuation and completion of all electrical testing for all systems and interfaces on the completed S-LRV, as required.

   b. Final installations of all equipment, button-up, clean-up and return to revenue conditions of the S-LRV.

   c. Final inspection of the S-LRV prior to delivery back to DART.

Over the weekend between Weeks #5 and #6, the completed S-LRV is moved from the Kinkisharyo facility adjacent to the Maintenance Yard back into the yard and into the DART shop. This movement of the S-LRV back to DART is combined and coordinated with the weekend movement of the LRV from Station #1 to Station #2, (see above).

6. Week #6, DART Shop and Maintenance Yard

    a. Delivery of completed S-LRV back to DART and joint (DART and Kinkisharyo) inspection and documentation of the status and state of repair of the S-LRV that is being returned to DART. This joint inspection occurs first thing on Monday mornings and is combined with the joint inspection on the LRV that is entering the conversion program, (see Week #1 above).

    b. The following activities are performed by DART:

        i. Wheel truing to match wheel diameters between the new wheels on the new trailer truck with the diameters of the exiting wheels on the other three trucks. Depending on the diameter of the wheels when the LRV enters the conversion program DART will either install new tires on the three old trucks to match the new wheels on the new truck or cut/reduce the diameter of the new wheels on the new trailer truck to match the existing wheels.

        ii. Re-leveling of the A, B and C units

        iii. Dynamic acceptance testing

        iv. ATP acceptance testing

        v. VBS acceptance testing

    c. Start of 1,000 mile burn-in operation to shake down and correct any nuisance issues before the car is accepted and released for revenue service.

7. Week #7, DART Shop and Main Line operation

    a. Continuation of 1,000 mile burn-in operation and correction of problems as required.

    b. Acceptance of the S-LRV and release for service.

    c. Depending on the number of problems that are encountered during testing and burn-in operation, availability of operators and other maintenance and operation requirements, the time to accumulate 1,000 miles of burn-in operation varies from car to car. Typically, an S-LRV meets the burn-in mileage requirement by the middle of Week #7 or early the following week after the weekend of operation.

Depending on the progress of the S-LRV that is completing the 1,000 mile burn-in, the number of cars in the conversion program varies between six and seven.

In addition to the S-LRV conversion program, a field modification program has been setup for the "mid-week" period to install the various engineering changes needed to correct unforeseen problems that were identified during the conversion program and/or revenue operation. The "field mod" car is delivered to Kinkisharyo on Tuesdays and is returned to DART on Thursdays.

This is an aggressive program that requires a lot of coordination. Cars move in and out of the yard every weekend. Cars move into and out of the field modification program every Tuesday and Thursday. Both DART and Kinkisharyo have to meet production line deadlines and commitments at the beginning, middle and end of each week. DART has to do this while maintaining and supporting revenue operation.

The conversion of S-LRVs started in January 2008. There was a slow start-up of the program because of the learning curve for the conversion. Since September 2008, the S-LRV conversion line has moved and one S-LRV has been returned to DART every week. The exception when an S-LRV is not

delivered is the week between Christmas and New Years when holidays and vacations limit the amount of work that can be completed. For all of the other one (or two) day holidays Kinkisharyo works overtime to complete the work and then supports the joint inspection of the LRV and S-LRV that occurs on Monday mornings. Since DART is a 24-hr/7-day operation the holidays are simply a part of normal activities.

As of March 12, 2010, 84 LRVs have been converted into S-LRVs with ATP and VBS, been accepted and returned to revenue service. The last of the 115 LRVs is scheduled to be converted into an S-LRV and returned to DART by October 2010. This will be just in time for the opening of the NW-SE "Green Line" and changing the entire DART LRT System to level boarding configuration (elimination of all "high-blocks" on the system) which is scheduled to occur in December 2010.

After an S-LRV is accepted it is returned to revenue service. Based on the extensive experience with the operation of the prototype the S-LRV can seamlessly be inserted into service to replace an LRV, in any train configuration:

- Single car train – An S-LRV can replace a single LRV and increase the capacity of that train.

- Two-car Train – An S-LRV can be used to replace either one or both of the LRVs in a two-car train with the corresponding increase in capacity. (In some cases, a two-car train in off-peak hours can be replaced with a single S-LRV)

- Three-car trains - Currently the length of the majority of the station platforms cannot accommodate a three-car train if an S-LRV is part of the consist. The capacity of a two-car S-LRV train is more than two LRVs but less than three LRVs. In most cases a two-car S-LRV consist can replace a three-car LRV consist and provide sufficient capacity.

FLEET EXPANSION FOR PHASE II

To complete the expansion of the fleet to meet the service requirements of the 88-mile LRT System when the Phase II Expansion is completed DART still had to increase passenger capacity and buy additional vehicles. Again, an in-depth cost analysis was performed and it was determined that the most cost effective course of action to expand the capacity of the fleet was to procure additional S-LRVs. In July 2008, DART awarded a contract to Kinkisharyo for 25 new S-LRVs with ATP VBS and Automatic Passenger Counters (APC). In October 2008 DART exercised an option to procure 23 additional S-LRVs for a total of 48 new S-LRVs. This will increase the size of the fleet to 163 S-LRVs, which is projected to meet the service requirements for the full Phase II Expansion. In addition to being the most cost-effective course of action, the continued use of S-LRVs had the same additional benefits as were identified for the S-LRV conversion program:

- Direct "level boarding" into the C-unit was provided for all cars

- Problems associated with operating and scheduling a mixed fleet of high and low floor cars were eliminated

- Problems associated with maintaining a mixed fleet of cars were eliminated

- Problems with stocking inventories of spare part for a mixed fleet were eliminated.

The first of the new 48 S-LRVs was delivered to DART in April, 2010 ready to start testing and burn-in operation in preparation for acceptance and release for service. The last of the 48 new S-LRVs is scheduled to be delivered in April 2011.

SUMMARY

From a technical point of view, the low floor center unit, "C-unit" project was a successful demonstration of how new capabilities and systems can be developed and added into an existing car. From an operational and maintenance point of view, the project was able to satisfy all of DART's requirements for increased service without the

disadvantages of having a mixed fleet operation. From a practical and financial point of view DART has been able to realize the most use and benefit of the existing fleet of LRVs, reduce the cost of increasing the capacity of the fleet to meet the requirements of the Phase II Expansion by approximately $50 million and partially defer the cost of converting the LRT System to level boarding configuration.

Overall, this has been a good example of an innovative idea that has withstood the objective scrutiny from all points of view and evolved into a real world, practical application that is being used daily, in actual revenue service.