DRAFT

Fort Worth Modern Streetcar

VEHICLE TECHNICAL REQUIREMENTS

JUNE 17, 2010

1. Type of Vehicle

The proposed alignment for the Fort Worth system will utilize city streets for the trackway and provide service via the use of streetcars. However, the term streetcar denotes a very diverse and large set of rail vehicles which, by some definitions, can include Light Rail Vehicles (LRV) as used by Dallas Area Rapid Transit (DART) in Dallas and the Metropolitan Transit Authority of Harris County (METRO) as well as more standard streetcar technologies such as those operated by Portland Streetcar Inc (PSI) in Portland and used on Seattle's Southlake Union Streetcar system. The diversity of vehicles available for consideration is primarily to accommodate the widely varying characteristics of alignments, service demands and performance needs. A major influence on the selection of the vehicle technology for any system is determined in large extent by the route the car needs to navigate.

The prime focus during vehicle technology conceptual level engineering efforts is to define the overall definition of the available vehicle options. This definition is critical, as different vehicles will have varying levels of impact on the overall alignment and the design of the civil infrastructure. The alignment imposes constraints on the vehicle and the vehicle imposes constraints on the alignment. Details of the proposed and selected vehicle's characteristics (seating layout, signage, air conditioning capacity, etc.) and operational requirements (braking rates, operating voltage, track gauge, etc.) will be addressed in the vehicle design criteria developed during the future preliminary engineering phase.

Another important factor in determining the type of vehicle is the overall impact the configuration will have on the streetscape and the visual aesthetics of its presence. While LRVs and other larger rail vehicles routinely operate on reserved right-of-way with dedicated areas for station stops, streetcars operate on the street next to sidewalks and businesses with curb extensions for boarding integrated into the sidewalks. The vehicle becomes the focal point of the entire system, integrated with the neighborhood, automotive traffic, and pedestrians at all locations.

The remainder of this section addresses specific issues that are important in determining the type of vehicle appropriate for operation in Fort Worth. The establishment of acceptable ranges for these items will determine the type of vehicle to be progressed into the future preliminary engineering phase. The specific issues are:

(1) Length;

(2) Width;

(3) Turning radius;

(4) Accessible boarding;

(5) Passenger capacity;

(6) Grades and vertical curves; and

(7) Off-wire operation capability (if needed).

1.1 Carbody Length

The length of the vehicle is important to the integration of the vehicle into the streetscape. The length of the vehicle and the position of its doors along the side are often determined by local on-street parking requirements. Platforms or curb extensions extending the entire length of the vehicle are not required if doors are not used along the entire carbody. The allowable length of the platform may be decided by local business concerns to take no more than one or two parking places. If a typical parking space is 22 feet (6.7 m) long and only two parking spaces may be used, then a short vehicle with no more than 44 feet (13.4 m) between the front and rear doors should be used.

The length of the vehicle is also important in its relationship to normal street traffic and the perception of the street ambience. A multiple unit LRV can occupy an entire lane for an entire block. This is one of the reasons LRV lines typically operate in exclusive reserved lanes when operating on city streets. One car in front of the train can result in the train blocking the intersection on the other side of the block. In downtown Fort Worth, block lengths are generally 240 – 260 feet long.

The diversity in streetcar lengths is illustrated in the pictures below. The first picture shows a 49 foot (15 m) low floor non-articulated streetcar. The second picture shows a 144 foot (44 m) tram with seven articulated sections.

Fig. 1 – Pragoimex Vario-LF2 - Ostrava

Fig. 2 - Alstom Citadis Type 402 – Bordeaux

1.2 Carbody Width

The width of the carbody is an important consideration for operation within a typical travel lane. The de-facto US standard for LRVs is 8 ft-8 in (2.65 m), although some cities such as Baltimore use a vehicle with a 10 ft (3.3 m) width. Streetcars have a much greater variation depending on the city and lane widths in which they operate. Streetcars vary from 7 ft-6½ in (2.3 m) to 8 ft-8 in (2.65 m) with the majority falling in the range of 7 ft-10½ in (2.4 m) to 8 ft-2½ in (2.5 m).

The platform extension from the curb is also fixed by the width of the carbody at the door thresholds. Compliance with the Americans with Disabilities Act (ADA) requires a horizontal gap of no more than 3 inches. This gap must also be sufficient to accommodate the dynamic envelope of the vehicle, particularly when towing another vehicle with a faulted suspension system on one side and leaning inward. The platform extension may also limit future procurements for the line to the same carbody width. An LRV cannot typically operate on an alignment designed for a narrower streetcar, even if all other parameters are compatible, as there may be interference with the platforms.

The issue of operating lane width is directly tied to the carbody vehicle width, including mirrors that extend beyond the limits of the carbody. As a general rule, before defining the exact vehicle parameters, one should consider the absolute minimum width of the lane that will have to accommodate the rail vehicle. At a minimum, evaluations should include the vehicle under all conditions on straight track considering the normal width of the carbody plus one foot (254 mm) on each side of the car. Additionally, Fort Worth may wish to add a 6 inch (125 mm) buffer to each side to allow for situations such as a parked car or delivery truck with mirrors overhanging the limits of any parallel parking along the curbside. Therefore, normal operations would require an 11 foot (3.4 m) lane without a buffer or a 12 foot (3.65m) lane with a buffer to accommodate an 8-foot (2.45 m) wide streetcar vehicle. A narrower street may require a narrower car and a wider street may allow a wider car.

The pictures below show the difference in widths of the Siemens Combino streetcar manufactured for two different systems. The Basel car is 7 ft-6½ in (2.3 m) and the Melbourne car is 8 ft-8 in (2.65 m).

Fig. 3 - Siemens Combino, Bern

Fig. 4 - Siemens Combino, Melbourne

2. Turning Radius and Clearance

The horizontal turning radius of a vehicle designed for operation on city streets is generally tighter than that required for LRVs. Almost all US LRVs are limited to a curve radius of 82 ft (25 m) whereas the typical streetcar can negotiate a curve of 65 ft (20 m) with some vehicles having the ability to operate on curves as tight as 50 ft (15 m).

The dynamic envelope of the vehicle needs to be accommodated in the design not only on straight trackway as discussed in the vehicle width section above, but also in curves. During curve negotiation, the dynamic envelope of the vehicle expands as determined by the distance between turning centers of the vehicle, distance from the front turning center to the end of the vehicle, and styling of the front end, whether squared or tapered. As such, the dynamic envelope on turns is specific to each specific vehicle. The figure below shows a typical clearance envelope for an 8ft 2½ in (2.5 m) vehicle with 28 ft (8.5 m) turning centers and a 10 ft (3.3 m) end overhang.

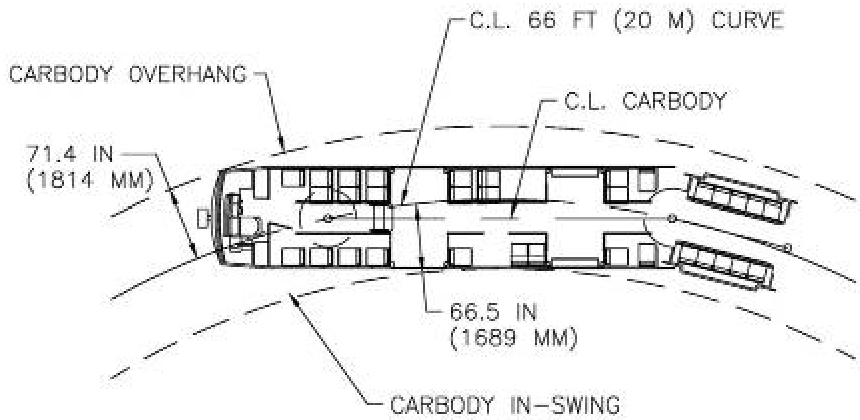

Fig. 5 – Typical Horizontal Turn Dynamic Envelope

This clearance envelope has a large impact on lane width in turns and can also affect the streetscape along the trackway. The figure below shows the possible impacts on wayside with turning a vehicle on a typical street corner where there are two twelve foot (3.6 m) travel lanes and two ten foot (3 m) parking lanes. When turning from the right-hand lane of one street to the right-hand lane of the next street, the impact on the corner is greater for the 82 foot (25 m) curve radius. These impacts are referred to as “corner clips” and may require property takes along the alignment or shifting the vehicle to the adjacent lane (multiple lane streets) to avoid existing structures. Proper selection of the carbody width and turning radius can minimize corner clips.

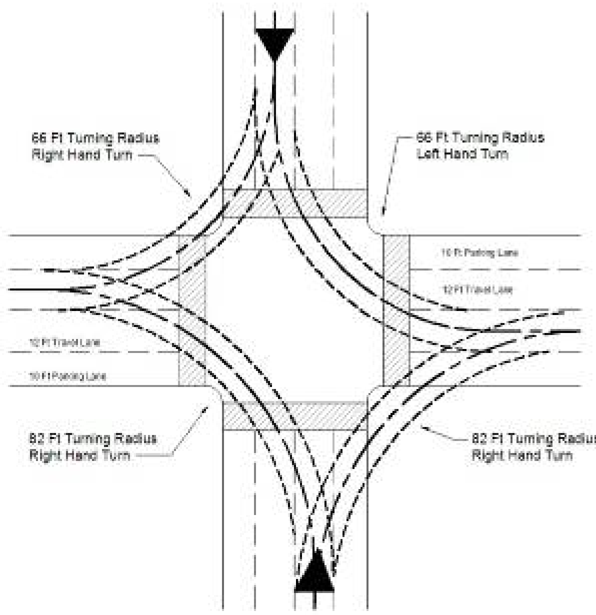

Fig. 6 - Corner Turning Radius

3. Accessible Boarding

Compliance with ADA is required by law. Most of the requirements for light rail vehicles are mandated by the Department of Transportation 49 CFR Part 38 and will be incorporated into a future vehicle technical specification used for procurement. The one area where compliance is largely determined by the operating agency preference is the method of accessible boarding. Accessible boarding may be accomplished by matching the platform height to the door threshold of the vehicle (level boarding) or using a lower platform height with a bridging device (bridgeplate) between the vehicle and platform.

Streetcar designs incorporate a standardized door threshold height of 14 inches (355 mm) in the low floor boarding area. A platform height of 14 inches (355 mm) will allow for level boarding without the use of a bridgeplate similar to a rapid transit vehicle or the Houston METRO LRV. This approach was used by Washington, DC on their initial order for streetcars. The drawback to this approach is the tall curb height at the end of the platform and tapering the platform back to the existing sidewalk that has a typical curb height of 7 inches (180 mm). The taper may be considered a ramp under ADA and have a maximum permissible slope of 1:12. The tapering of the platform can also affect drainage and water must be prevented from draining into any structure on the back of the sidewalk.

To minimize these issues several cities, including Portland and Seattle, have used bridgeplates to board from a 10-inch high platform. The bridgeplates are stored under the door threshold in the vehicle's underframe structure and extend on command by the Operator to provide an accessible entrance. A deployed bridgeplate is shown in the photo below.

Fig. 7 - Extension of Bridgeplate for Boarding

An important issue to consider during the development of the preferred alignment regarding platform height is whether or not buses will be serving the same platforms as the streetcars. Most buses have wheelchair ramps that deploy from the front door of the bus and must have a platform height of nine inches (225 mm) or less. A platform height of 14 inches (355 mm) for level boarding is difficult to ramp down to a height suitable for operation with the front door mounted bus lifts. The taller 14 inch (355 mm) platform height may also prevent the opening of the rear doors on the bus at shared platforms. If buses are to utilize the same platforms, the 10 inch (255 mm) platform height is recommended.

4. Passenger Capacity

The passenger capacity of a vehicle is directly related to its length and width. For LRVs and other vehicles incorporating an 8 ft-8 in (2.65 m) width, four abreast seating with a center aisle is possible except in areas designated for wheelchair accessibility. Smaller width vehicles generally use two seats on one side of the aisle and one seat on the other side, such as the Tacoma streetcar shown below.

Figure 8 – Tacoma Streetcar Interior

One of the items to notice in the picture above is the amount of open space in the low floor center section for wheelchairs and standees. Streetcar trips tend to be shorter within the urban center as opposed to typical LRV service operating from a suburb to the city center. For these short trips, standing is typically more acceptable to passengers and using open areas for standees can significantly increase the passenger capacity of the vehicle over installing additional seating.

5. Grades and Vertical Curves

The grades and vertical curves found on the trackway will influence and constrain the types of vehicles that can be used. LRV alignments tend to be designed specifically with the performance capabilities of the rail vehicle in mind and accommodate grades limited to 7% and vertical curves limited to a sag of 1150 ft (350 m). Streetcars are installed on trackways in streets designed for automobile traffic where grades and vertical curves are not as tightly controlled and the construction budgets do not typically allow for rebuilding the streets.

The maximum gradient a streetcar can reliably negotiate depends more on the adhesion of the steel wheel on steel rail interface than of any other parameter. The installed power can always be increased but the physics of friction limit the maximum grade that can be handled. As a rule of thumb, streetcars with all trucks powered (100% adhesion) can reliably operate on grades of up to 9% under typical weather conditions. LRVs or streetcars with two of three trucks powered (67% adhesion) can operate on grades of up to 7% and streetcars that have one of two or one of three trucks powered can only negotiate grades of 4 to 5%. The route chosen for the streetcar is limited by these capabilities and the number of powered trucks on the streetcar is determined by the route chosen.

Vertical curve capabilities are important primarily when considering overpasses and underpasses that may be encountered along the route. A typical underpass, as would be used to pass under a mainline railroad, will have a tight vertical sag curve at the bottom of the underpass and a tight crest curve at the top, see the below Figure. The ability of the vehicle to negotiate this unique curve geometry is dependent on the vehicle and its articulation systems and is very expensive to modify. The required radius must be included in the final vehicle specification.

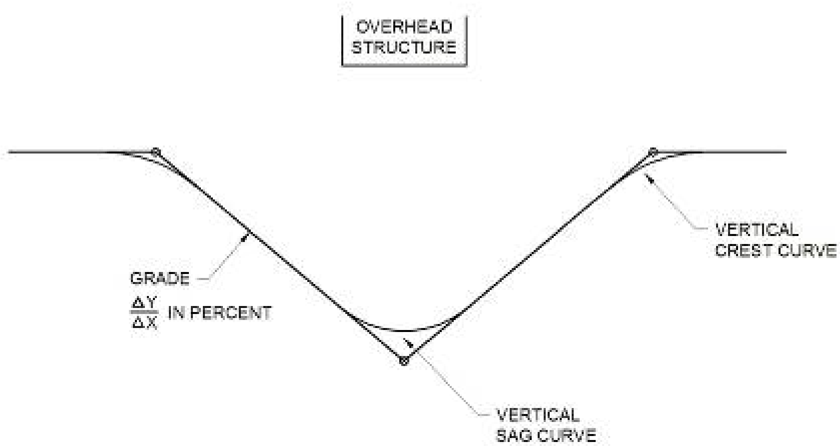

Fig. 9 – Typical Underpass Curves

6. Off Wire Operation

Off wire operation of rail vehicles in the US has been limited to the emergency drive option provided in the streetcars currently in revenue service in Portland, Tacoma, and Seattle. This drive mode is operated from the 24 Vdc battery supply and is very limited in both speed and distance. The low voltage and high currents required stress the propulsion system thermal capacity such that only about 1,000 feet (330 m) of movement can be made at speeds of 1-2 mph (2-3 km/h).

Currently, many US transit agencies have begun to investigate operation at higher speeds and longer distances, though none are in service at this time. The reasons for desiring off wire operation include the protection of historically unique areas, low clearance underpasses, overhead trolley bus lines at a different voltage, or high clearance requirements for crossing active freight railroads.

Operation in revenue service with high voltage batteries or super-capacitors is currently being developed by almost all major streetcar suppliers. European cities such as Nice, Graz, and Mannheim have such systems in operation. The distances traveled off wire are up to one-half mile, though other systems with more capacity are achieving distances of 3 miles or more in prototype testing. This is “cutting edge” technology and the additional price per vehicle can be up to $500,000. Consideration of the need to use off wire operation technology must be carefully evaluated, and the costs and risk associated with such use must be included in the overall system plan.

7. Representative Vehicles

The following section contains brief descriptions of several vehicles where the manufacturer has previously provided streetcars for passenger service or is known to be interested in the North American market accommodating the criteria identified in the previous sections. Due to the small fleet size of the anticipated vehicle procurement, the development of a custom vehicle is not addressed, and is not recommended for cost reasons. Discussion is also limited to production models that would only need minor modifications to work in Fort Worth with the anticipated small order size limiting the ability to distribute engineering costs acceptably.

There are essentially five representative suppliers of shorter vehicles suitable for operation in city streets covering four different models. The suppliers are Inekon, Oregon Iron Works (OIW), Siemens, Bombardier, and Kinki Sharyo. The Inekon and Oregon Iron Works cars are virtually the same with Oregon Iron Works currently developing a copy of the earlier 10T streetcar supplied by Inekon to Portland and Seattle prior to 2004. The procurement effort for Fort Worth should not be limited to these five potential suppliers; however, information on these is readily available for consideration at this stage. All noted suppliers either have produced vehicles meeting FTA requirements for Buy America or claim to be capable of meeting such requirements.

Pictures of the four models are shown below.

Fig. 10 – Bombardier, Toronto

Fig. 11 - Inekon 12T Vehicle, Washington DC

Fig. 12 - Kinki Sharyo J-Tram Prototype (in construction)

Fig. 13 - Siemens S70, Charlotte (Longer Version)

7.1 Order History

The following table shows currently known orders for modern streetcars in the US and Canada. The table includes actual orders, contract awards, prototypes, and orders likely to be placed in the near future.

Supplier	City	Quantity	NTP Date	Service Date	Price 1)
Inekon	Portland	5	1999	2001	$1.9 M
Inekon	Tacoma	3	1999	2001	$1.9 M
Inekon	Portland	1	2001	2003	$1.7 M *
Inekon	Portland	1	2002	2004	$1.9 M *
Inekon	Washington	3	2005	2)	$2.8 M
Inekon	Portland	3	2005	2007	$2.7 M
Inekon	Seattle	3	2005	2007	$2.7 M
OIW	Portland	1	2006	3)	$3.7 M *
Bombardier	Toronto	204	2009	2012	$4.8 M *
OIW	Portland	6	2009	2012	$3.3 M * 4)
Siemens	Salt Lake City	77	2008	2012	$3.6 M
Kinki Sharyo	Prototype	1	5)		
OIW	Tucson	7			$3.7 M 6)

Notes:

1) Pricing includes total contract cost including support and spare parts. Where the price is for the vehicle only, an asterisk is shown after the number. These numbers are approximate and should be used for budgetary purposes only.
2) The Washington, DC cars were tested and verified for proper operation at the manufacturer's facility. However, the alignment in DC is not yet complete and the vehicles are being stored until revenue service begins
3) The Oregon Iron Works vehicle was a prototype copy of the original Inekon design. It was delivered in May 2009 and could not be qualified for revenue service. In May 2010, it was returned to the manufacturer's facility for extensive retrofitting.
4) The original contract price and delivery is currently being re-negotiated. A substantial increase in price is anticipated.
5) The Kinki Sharyo prototype is being built at the contractor's expense without a firm order. The prototype is expected to arrive in the Dallas area in the fall of 2010 for industry evaluation.
6) The contract award pricing is being re-negotiated prior to NTP from Tucson. A substantial increase in price is expected if NTP is exercised.

8. Vehicle Size and Characteristics

The following table shows the basic vehicle size and arrangement characteristics for the five noted manufacturers.

Supplier	Length	Width	% Low Floor	ADA Boarding	Capacity Seated (Full)
Bombardier	92’ (28 m)	8’-4” (2.54 m)	100	No	62 (245)
Inekon	66’ (20 m)	8’-0” (2.46 m)	50	Bridgeplate or Level	30 (115)
Kinki Sharyo	66’ (20 m)	8’-8½” (2.65 m)	100	Level	28 (119)
OIW	66’ (20 m)	8’-0” (2.46 m)	50	Bridgeplate	30 (115)
Siemens	79’ (24.1 m)	8’-8½” (2.65 m)	50	Bridgeplate	64 (220)

9. Alignment Constraints

The following table shows the constraints placed on the alignment for the five representative manufacturers.

Supplier	Turn Radius	Grade	Crest Curve	Sag Curve	Off-Wire
Bombardier	36’ (11 m)	8%	397’ (121 m)	800’ (243 m)	No
Inekon	59’ (18 m)	9%	820’ (250 m)	820’ (250 m)	Emergency Moves Only
Kinki Sharyo	59’ (18 m)	7%	1148‘ (350 m)	1148’ (350 m)	Yes, 3 miles
OIW	59’ (18 m)	9%	820’ (250 m)	820’ (250 m)	Emergency Moves Only
Siemens	82’ (25m)	7%	820’ (250 m)	1148’ (350 m)	No

Of particular note is the cost of the Bombardier vehicle supplied to Toronto. One of the primary driving forces for the high cost is the characteristics of the alignment. The tight horizontal curve radius of 36’ (11 m) and vertical curve radius of 397’ (121 m) make this a custom-engineered car and the price of $4.8 M each reflects the difficulty of distributing the costs even over an order of 204 vehicles. The selection of the Fort Worth alignment should strongly consider commonly available vehicles.

10. Procurement Approach

The procurement approach should accommodate a wide variety of offerings, some of which may be new to the North American market. The primary challenge lies in how to procure a small quantity of vehicles, like what is anticipated for the Fort Worth fleet, without allowing the engineering and administrative costs to overwhelm the base price of the vehicle. Additionally, some of the offerings may not have been manufactured for the American market and adjustment of the initial offers may be necessary to achieve the best car at the best price. For this reason, a two-step procurement process is recommended. This process will include steps where proposals from suppliers are solicited, received, and reviewed by Fort Worth, and then at Fort Worth's option, a second round may be initiated to receive a Best and Final Offer.

10.1 Preparation of Procurement Documents

Procurement documents specifying both the commercial terms and the technical requirements of the vehicles should be produced. Generally, two separate volumes are generated, referred to as the Commercial Provisions and the Technical Provisions.

The Commercial Provisions define the commercial terms for the supplier, including payment schedule, shipping and delivery, warranty, and all Federal, State, and local conditions for the contract. Federal provisions will apply if Federal Transportation Agency funds are used for the system. These provisions will include Buy America requirements. It is important to note that there is no modern streetcar in service in North America that meets the Buy America requirements. Several of the potential suppliers are experienced with Buy America from previous LRV procurements, but at least one potential supplier has no experience with these provisions. The ability to accommodate the available funding mechanisms with an available vehicle platform is critical.

The Technical Provisions spell out the technical details of designing, manufacturing, and qualifying the vehicle for revenue service. Using the vehicle design criteria developed during the future preliminary engineering effort and expressions of interest from potential suppliers, a specification will be developed that includes all possible vehicle configurations and accommodates Fort Worth's requirements. A primary goal of the specification development will be to minimize the changes needed to a potential supplier's "off-the-shelf" vehicle and consequently hold the engineering costs to the supplier, and hence to Fort Worth, to acceptable levels.

To help expedite the procurement process, it is recommended that steps be included that allow potential suppliers to indicate where the technical specifications may conflict with an existing design platform they wish to offer. This important step can be accommodated by circulating draft versions of the procurement documents for review and comment by suppliers.

During this phase of the process, meetings may be held with all potential suppliers to discuss both commercial and technical matters prior to issuance of the final Request for Proposals.

11. Request for Proposals

Once the industry review effort has been completed, a set of revised Commercial and Technical Specifications and the Request for Proposal (RFP) will be prepared and issued. Due to the previous steps noted above, all potential suppliers will have a good understanding of the procurement requirements and a relatively short time can be allowed for submission of proposals. Once the RFP is issued, all informal communications between project personnel and potential proposers are terminated and all communications are conducted formally through one point-of-contact. This ensures no potential proposer receives any information that may be advantageous in the procurement.

Prior to issuance of the RFP, Fort Worth will develop detailed evaluation criteria to be used to evaluate the RFPs received. The general outline of the evaluation criteria, e.g. percent applied to the price and technical scores, are normally published in the RFP. The detailed criteria are developed internally and can include the price weighting for base vehicles versus option vehicles, the weighting given to the aesthetics of the vehicle by community representatives, and the weighting given to individual systems on the vehicle such as propulsion or HVAC. These criteria will be used to develop an unbiased overall score and ranking for each vehicle proposal received.

After the evaluation and ranking of the received RFPs, Fort Worth may elect to accept an initial proposal or conduct a second round referred to as a Best and Final Offer (BAFO). The second round may go to all proposers or only to those within a predetermined “competitive range”. The BAFO process allows proposers to adjust specific deficiencies in their proposal, Fort Worth to modify the requirements to accommodate alternatives, and for proposers to lower their price. This use of a competitive range conserves resources on the BAFO by eliminating proposals that are not in the best interest of Fort Worth to pursue.

After receipt of the BAFOs the proposals are scored a second time and the highest ranked proposer is awarded the contract.

12. Preliminary Timeline for Procurement

The following is a preliminary timeline based on the two-step procurement described above.

Month	Activity
0	Solicit suppliers for interest with letter and design criteria
0	Begin development of Commercial and Technical Provisions
3	Publish for industry review and conduct any meetings, if necessary
5	Issue RFP
7	Receive and evaluate proposals
10	Issue NTP
27	Delivery of first vehicle
32	Initiate Service