ANNEX F (INFORMATIVE) DATA CENTER INFRASTRUCTURE TIERS

This annex is informative only and is not part of this Standard.

F.1 General

It should be noted that human factors and operating procedures may have a greater impact on availability than the tier rating of the data center. This tiering scheme suggests a limited set of steps intended to improve data center reliability. It is not intended to be all-inclusive. Additional or alternative schemes are available in other standards.

F.1.1 Redundancy overview

Single points of failure should be eliminated to improve redundancy and reliability, both within the data center and support infrastructure as well as in the external services and utility supplies.

This Standard includes four tiers relating to various level of resiliency of the data center facility infrastructure. The tier ratings correspond to the industry data center tier ratings as defined by The Uptime Institute, but the definitions of each tier have been expanded in this Standard.

F.1.2 Tiering overview

This Standard includes four tiers relating to various levels of resiliency of the data center facility infrastructure. Higher tiers not only correspond to higher resiliency, but also lead to higher construction costs. In all cases, higher rated tiers are inclusive of lower level tier requirements unless otherwise specified.

A data center may have different tier ratings for different portions of its infrastructure. For example, a data center may be rated tier 3 for electrical, but tier 2 for mechanical. For the sake of simplicity, a data center that is rated the same for all subsystems (telecommunications, architectural and structural, electrical and mechanical) can be called out by its tier overall (e.g. a tier 2 data center would have a tier 2 rating in all subsystems). However where not all portions of the infrastructure are at the same level, the tiering should be called out specifically. For example, a data center may be a tier rating of T_2 E_3 A_1 M_2 where:

- telecommunications is tier 2 (T_2);
- electrical is tier 3 (E_3);
- architectural infrastructure is tier 1 (A_1); and
- mechanical infrastructure is tier 2 (M_2).

Although typically a data center's overall rating is based on its weakest component, there may be mitigating circumstances relative to that facilities specific risk profile, operational requirements or other factors that justify the lower rating in one or more subsystems.

Different areas within a data center may also be built and or used at different tier levels dependant on operational needs. In such cases care should be given to describe these differences, for example an area of a data center that has a tier 2 risk avoidance profile because it has T_2, E_2, A_2 M_2 services within a facility that may be Tier 3.

Care should be taken to maintain mechanical and electrical system capacity to the correct tier level as the data center load increases over time. For example, a data center may be degraded from tier 3 or tier 4 to tier 1 or tier 2 as redundant capacity is utilized to support new computer and telecommunications equipment.

F.2 Redundancy

F.2.1 N - Base requirement

System meets base requirements and has no redundancy.

F.2.2 N+1 redundancy

N+1 redundancy provides one additional unit, module, path, or system in addition to the minimum required to satisfy the base requirement. The failure or maintenance of any single unit, module, or path will not disrupt operations.

F.2.3 N+2 redundancy

N+2 redundancy provides two additional units, modules, paths, or systems in addition to the minimum required to satisfy the base requirement. The failure or maintenance of any two single units, modules, or paths will not disrupt operations.

F.2.4 2N redundancy

2N redundancy provides two complete units, modules, paths, or systems for every one required for a base system. Failure or maintenance of one entire unit, module, path, or system will not disrupt operations.

F.2.5 2(N+1) redundancy

2 (N+1) redundancy provides two complete (N+1) units, modules, paths, or systems. Even in the event of failure or maintenance of one unit, module, path, or system, some redundancy will be provided and operations will not be disrupted.

F.2.6 Concurrent maintainability and testing capability

The facilities should be capable of being maintained, upgraded, and tested without interruption of operations.

F.2.7 Capacity and scalability

Data centers and support infrastructure should be designed to accommodate future growth with little or no disruption to services.

F.2.8 Isolation

Data centers should be (where practical) used solely for the purposes for which they were intended and should be isolated from non-essential operations.

F.2.9 Data center tiering

The four data center tiers as originally defined by The Uptime Institute in its white paper ”Industry Standard Tier Classifications Define Site Infrastructure Performance” are:

Tier I Data Center: Basic

A Tier I data center is susceptible to disruptions from both planned and unplanned activity. If it has UPS or generators, they are single-module systems and have many single points of failure. The infrastructure should be completely shut down on an annual basis to perform preventive maintenance and repair work. Urgent situations may require more frequent shutdowns. Operation errors or spontaneous failures of site infrastructure components will cause a data center disruption.

Tier II Data Center: Redundant Components

Tier II facilities with redundant components are slightly less susceptible to disruptions from both planned and unplanned activity than a basic data center. They have UPS, and engine generators, but their capacity design is “Need plus One” (N+1), which has a single-threaded distribution path throughout. Maintenance of the critical power path and other parts of the site infrastructure will require a processing shutdown.

Tier III Data Center: Concurrently Maintainable

Tier III level capability allows for any planned site infrastructure activity without disrupting the computer hardware operation in any way. Planned activities include preventive and programmable maintenance, repair and replacement of components, addition or removal of capacity components, testing of components and systems, and more. Sufficient capacity and distribution must be available to simultaneously carry the load on one path while performing maintenance or testing on the other path. Unplanned activities such as errors in operation or spontaneous failures of facility infrastructure components may still cause a data center disruption.

Tier IV Data Center: Fault Tolerant

Tier IV provides site infrastructure capacity and capability to permit any planned activity without disruption to the critical load. Fault-tolerant functionality also provides the ability of the site infrastructure to sustain at least one worst-case unplanned failure or event with no critical load impact. This requires simultaneously active distribution paths, typically in a System+System configuration.

F.3 Telecommunications

Figure 12 in clause 9 illustrates data center telecommunications cabling pathway infrastructure redundancy at various tiers.

F.3.1 Tier 1 (telecommunications)

In addition to the requirements and guidelines in this standard, a tier 1 facility will have one customer owned maintenance hole and entrance pathway to the facility. The access provider services will be terminated within one entrance room. The communications infrastructure will be distributed from the entrance room to the main distribution and horizontal distribution areas (HDAs) throughout the data center via a single pathway. Although logical redundancy may be built into the network topology, there would be no physical redundancy or diversification provided within a tier 1 facility.

Some potential single points of failure of a tier 1 facility are:

- access provider outage, central office outage, or disruption along a access provider right-of-way;
- access provider equipment failure;
- router or switch failure, if they are not redundant;
- any catastrophic event within the entrance room, main distribution area (MDA), or maintenance hole may disrupt all telecommunications services to the data center; and
- damage to backbone or horizontal cabling.

F.3.2 Tier 2 (telecommunications)

The telecommunications infrastructure should meet the requirements of tier 1.

Critical telecommunications equipment, access provider provisioning equipment, production routers, production LAN switches, and production SAN switches, should have redundant components (power supplies, processors).

Intra-data center LAN and SAN backbone cabling from switches to backbone switches should have redundant fiber or wire pairs within the overall star configuration. The redundant connections may be in the same or different cable sheaths.

Logical configurations are possible and may be in a ring or mesh topology superimposed onto the physical star configuration.

A tier 2 facility addresses vulnerability of telecommunications services entering the building.

A tier 2 facility should have two customer owned maintenance holes and entrance pathways to the facility. The two redundant entrance pathways will be terminated within one entrance room.

All patch cords and jumpers should be labeled at both ends of the cable with the name of the connection at both ends of the cable.

Some potential single points of failure of a tier 2 facility are:

- access provider equipment located in the entrance room connected to same electrical distribution and supported by single HVAC components or systems;
- redundant LAN or SAN switches connected to same electrical circuit or supported by single HVAC components or systems; and
- any catastrophic event within the entrance room or MDA may disrupt all telecommunications services to the data center.

F.3.3 Tier 3 (telecommunications)

The telecommunications infrastructure should meet the requirements of tier 2.

The data center should be served by at least two access providers. Service should be provided from at least two different access provider central offices or points-of-presences. Access provider cabling from their central offices or points-of-presences should be separated by at least 20 m (66 ft) along their entire route for the routes to be considered diversely routed.

The data center should have two entrance rooms preferably at opposite ends of the data center but a minimum of 20 m (66 ft) physical separation between the two rooms. Do not share access provider provisioning equipment, fire protection zones, power distribution units, and air conditioning equipment between the two entrance rooms. The access provider provisioning equipment in each entrance room should be able to continue operating if the equipment in the other entrance room fails.

The data center should have redundant backbone pathways between the entrance rooms, MDA, intermediate distribution areas (IDAs), and HDAs.

Intra-data center LAN and SAN backbone cabling from switches to backbone switches should have redundant fiber or wire pairs within the overall star configuration. The redundant connections should be in diversely routed cable sheathes.

There should be a “hot” standby backup for all critical telecommunications equipment, access provider provisioning equipment, core layer production routers and core layer production LAN/SAN switches.

All cabling, cross-connects and patch cords should be documented using software systems or automated infrastructure management systems as described in the ANSI/TIA-606-B.

Some potential single points of failure of a tier 3 facility are:

- any catastrophic event within the MDA may disrupt all telecommunications services to the data center; and
- any catastrophic event within a HDA may disrupt all services to the area it servers.

F.3.4 Tier 4 (telecommunications)

The telecommunications infrastructure should meet the requirements of tier 3.

Data center backbone cabling and distributor locations should be redundant. Cabling between two spaces should follow physically separate routes, with common paths only inside the two end spaces. Backbone cabling should be protected by routing through conduit or by use of cables with interlocking armor.

There should be automatic backup for all critical telecommunications equipment, access provider provisioning equipment, core layer production routers and core layer production LAN/SAN switches. Sessions/connections should switch automatically to the backup equipment.

The data center should have redundant MDAs preferably at opposite ends of the data center, but a minimum of 20 m (66 ft) physical separation between the two spaces. Do not share fire protection zones, power distribution units, and air conditioning equipment between the redundant

MDAs. The redundant MDA is optional, if the computer room is a single continuous space, as there is probably little to be gained by implementing two MDAs in this case.

The two MDAs should have separate pathways to each entrance room. There should also be a pathway between the MDAs.

The redundant routers and switches should be distributed between redundant distribution spaces (e.g. redundant MDAs, redundant pair of IDAs, or redundant pair of HDAs, or redundant pair of entrance rooms).

Each HDA should be provided with connectivity to two different IDAs or MDAs. Similarly, each IDA should be provided with connectivity to both MDAs.

Critical systems should have horizontal cabling to two HDAs.

Some potential single points of failure of a tier 4 facility are at:

- the MDA (if the secondary distribution area is not implemented); and
- the HDA and horizontal cabling (if redundant horizontal cabling is not installed).

F.4 Architectural and structural

F.4.1 General

The building structural system should be either steel or concrete. At a minimum, the building frame should be designed to withstand wind loads in accordance with the applicable building codes for the location under consideration and in accordance with provisions for structures designated as essential facilities (for example, Building Classification III from the International Building Code).

F.4.2 Tier 1 (architectural)

Architecturally, a tier 1 data center is a data center with no requirements for protection against physical events, intentional or accidental, natural or man-made, which could cause the data center to fail.

F.4.3 Tier 2 (architectural)

Tier 2 installations should meet all requirements of tier 1. A tier 2 data center includes additional minimal protections against some physical events, intentional or accidental, natural or man-made, which could cause the data center to fail.

F.4.4 Tier 3 (architectural)

Tier 3 installations should meet all requirements of tier 2. A tier 3 data center has protection against most physical events, intentional or accidental, natural or manmade, which could cause the data center to fail.

F.4.5 Tier 4 (architectural)

A tier 4 data center has considered all potential physical events that could cause the data center to fail. A tier 4 data center has provided specific and in some cases redundant protections against such events. Tier 4 data centers consider the potential problems with natural disasters such as seismic events, floods, fire, hurricanes, and storms, as well as potential problems with terrorism and disgruntled employees. Tier 4 data centers have control over all aspects of their facility.

F.5 Electrical

F.5.1 Tier 1 (electrical)

A tier 1 facility provides the minimum level of power distribution to meet the electrical load requirements, with little or no redundancy. The electrical systems are single path, whereby a failure of or maintenance to a panel or feeder will cause partial or total interruption of operations. No redundancy is required in the utility service entrance.

Generators may be installed as single units or paralleled for capacity, but there is no redundancy requirement. One or more automatic transfer switches are typically used to sense loss of normal power, initiation of generator start and transfer of loads to the generator system. Isolation-bypass automatic transfer switches (ATSs) or automatic transfer circuit breakers are used for this purpose but not required. Permanently installed load banks for generator and UPS testing are not required. Provision to attach portable load banks is required.

The uninterruptible power supply system can be installed as a single unit or paralleled for capacity. Static, rotary or hybrid UPS technologies can be utilized, with either double conversion or line interactive designs. Compatibility of the UPS system with the generator system is required. The UPS system should have a maintenance bypass feature to allow continuous operation during maintenance of the UPS system.

Separate transformers and panel boards are acceptable for the distribution of power to the critical electronic loads in tier 1 data centers. The transformers should be designed to handle the non-linear load that they are intended to feed. Harmonic canceling transformers can also be used in lieu of K-rated transformers.

Power distribution units (PDU) or discrete transformers and panel boards may be used to distribute power to the critical electronic loads. Any code compliant wiring method may be utilized. Redundancy is not required in the distribution system. Grounding system should conform to minimum code requirements.

Monitoring of electrical and mechanical systems is optional.

F.5.2 Tier 2 (electrical)

Tier 2 installations should meet all requirements of tier 1. In addition,

A tier 2 facility provides for N+1 redundant UPS modules. A generator system sized to handle all data center loads is required, although redundant generator sets are not required. No redundancy is required in the utility service entrance or power distribution system.

Provisions to connect portable load banks should be provided for generator and UPS testing.

Power distribution units (PDUs) should be used to distribute power to the critical electronic loads. Panel boards or PDU “sidecars” may be sub-fed from PDUs where additional branch circuits are required. Two redundant PDUs, each preferably fed from a separate UPS system, should be provided to serve each computer equipment rack; single cord and three cord computer equipment should be provided with a rack-mount fast-transfer switch or static switch fed from each PDU. Alternatively, dual-fed static-switch PDUs fed from separate UPS systems can be provided for single cord and three-cord equipment, although this arrangement offers somewhat less redundancy and flexibility. Color-coding of nameplates and feeder cables to differentiate A and B distribution should be considered, for example, all A-side white, all B-side blue.

A circuit should not serve more than one rack to prevent a circuit fault from affecting more than one rack. To provide redundancy, racks and cabinets should each have two dedicated electrical circuits fed from two different Power Distribution Units (PDUs) or electrical panels. Each receptacle should be identified with the PDU and circuit number, which serves it. Redundant feeder to mechanical system distribution board is recommended but not required.

F.5.3 Tier 3 (electrical)

Tier 3 installations should meet all requirements of tier 2.

All systems of a tier 3 facility should be provided with at least N+1 redundancy at the module, pathway, and system level, including the generator and UPS systems, the distribution system, and all distribution feeders. The configuration of mechanical systems should be considered when designing the electrical system to ensure that N+1 redundancy is provided in the combined electrical-mechanical system. This level of redundancy can be obtained by either furnishing two sources of power to each air conditioning unit, or dividing the air conditioning equipment among multiple sources of power. Feeders and distribution boards are dual path, whereby a failure of or maintenance to a cable or panel will not cause interruption of operations. Sufficient redundancy should be provided to enable isolation of any item of mechanical or electrical equipment as required for essential maintenance without affecting the services being provided with cooling. By employing a distributed redundant configuration, single points of failure are virtually eliminated from the utility service entrance down to the mechanical equipment, and down to the PDU or computer equipment.

To increase the availability of power to the critical load, the distribution system is configured in a distributed isolated redundant (dual path) topology. This topology requires the use of automatic static transfer switches (ASTS) placed either on the primary or secondary side of the PDU transformer. Automatic static transfer switches (ASTS) requirements are for single cord load only. For dual cord (or more) load design, affording continuous operation with only one cord energized, no automatic static transfer switches (ASTS) is used, provided the cords are fed from different UPS sources. The automatic static transfer switches (ASTS) will have a bypass circuit and a single output circuit breaker.

A central power and environmental monitoring and control system (PEMCS) should be provided to monitor all major electrical equipment such as main switchgears, generator systems, UPS systems, automatic static transfer switches (ASTS), power distribution units, automatic transfer switches, motor control centers, transient voltage surge suppression systems, and mechanical systems. A separate programmable logic control system should be provided, programmed to manage the mechanical system, optimize efficiency, cycle usage of equipment and indicate alarm condition.

F.5.4 Tier 4 (electrical)

Tier 4 installations should meet all requirements of tier 3.

Tier 4 facilities should be designed in a ‘2(N+1)’ configuration in all modules, systems, and pathways. All feeders and equipment should be capable of manual bypass for maintenance or in the event of failure. Any failure will automatically transfer power to critical load from failed system to alternate system without disruption of power to the critical electronic loads.

A battery monitoring system capable of individually monitoring the impedance or resistance of each cell and temperature of each battery jar and alarming on impending battery failure should be provided to ensure adequate battery operation.

The utility service entrances should be dedicated to the data center and isolated from all non-critical facilities.

The building should have at least two utility feeders from different utility substations for redundancy.

F.6 Mechanical systems

F.6.2 Tier 1 (mechanical)

The HVAC system of a tier 1 facility includes single or multiple air conditioning units with the combined cooling capacity to maintain critical space temperature and relative humidity at design conditions with no redundant units. If these air conditioning units are served by a water-side heat rejection system, such as a chilled water or condenser water system, the components of these systems are likewise sized to maintain design conditions, with no redundant units. The piping system or systems are single path, whereby a failure of or maintenance to a section of pipe will cause partial or total interruption of the air conditioning system.

If a generator is provided, all air-conditioning equipment should be powered by the standby generator system.

F.6.2 Tier 2 (mechanical)

The HVAC system of a tier 2 facility includes multiple air conditioning units with the combined cooling capacity to maintain critical space temperature and relative humidity at design conditions, with one redundant unit (N+1). If these air conditioning units are served by a water system, the components of these systems are likewise sized to maintain design conditions, with one redundant unit(s). The piping system or systems are single path, whereby a failure of or maintenance to a section of pipe will cause partial or total interruption of the air conditioning system.

Air-conditioning systems should be designed for continuous operation 7 days/24 hours/365 days/year, and incorporate a minimum of N+1 redundancy in the Computer Room Air Conditioning (CRAC) units.

The computer room air conditioners (CRAC) system should be provided with N+1 redundancy, with a minimum of one redundant unit for every three or four required units.

All air-conditioning equipment should be powered by the standby generator system.

Power circuits to the air-conditioning equipment should be distributed among a number of power panels/distribution boards to minimize the effects of electrical system failures on the air-conditioning system.

All temperature control systems should be powered through redundant dedicated circuits from the UPS.

Air supply to the data center should be coordinated with the types and layouts of the server racks to be installed. The air handling plant should have sufficient capacity to support the total projected heat load from equipment, lighting, the environment, etc., and maintain constant relative humidity levels within the data center. The required cooling capacity should be calculated based on the kW (not kVA) supply available from the UPS system.

Redundancy and isolation should be provided in the fuel storage system to ensure that fuel system contamination or a mechanical fuel system failure does not affect the entire generator system.

F.6.3 Tier 3 (mechanical)

The HVAC system of a tier 3 facility includes multiple air conditioning units with the combined cooling capacity to maintain critical space temperature and relative humidity at design conditions, with sufficient redundant units to allow failure of or service to one electrical switchboard. If these air conditioning units are served by a water-side heat rejection system, such as a chilled water or condenser water system, the components of these systems are likewise sized to maintain design conditions, with one electrical switchboard removed from service. This level of redundancy can be obtained by either furnishing two sources of power to each air conditioning unit, or dividing the air conditioning equipment among multiple sources of power. The piping system or systems are dual path, whereby a failure of or maintenance to a section of pipe will not cause interruption of the air conditioning system.

Redundant computer room air conditioning (CRAC) units should be served from separate panels to provide electrical redundancy. All computer room air conditioners (CRAC) units should be backed up by generator power.

Refrigeration equipment with N+1, N+2, 2N, or 2(N+1) redundancy should be dedicated to the data center. Sufficient redundancy should be provided to enable isolation of any item of equipment as required for essential maintenance without affecting the services being provided with cooling.

Subject to the number of Precision Air Conditioners (PAC’s) installed, and consideration of the maintainability and redundancy factors, cooling circuits to the Precision Air Conditioners (PAC's) should be sub-divided. If chilled water or water-cooled systems are used, each data center dedicated sub-circuit should have independent pumps supplied from a central water ring circuit. A water loop should be located at the perimeter of the data center and be located in a sub floor trough to contain water leaks to the trough area. Leak detection sensors should be installed in the trough. Consideration should be given to fully isolated and redundant chilled water loops.

F.6.4 Tier 4 (mechanical)

The HVAC system of a tier 4 facility includes multiple air conditioning units with the combined cooling capacity to maintain critical space temperature and relative humidity at design conditions, with sufficient redundant units to allow failure of or service to one electrical switchboard. If these air conditioning units are served by a water-side heat rejection system, such as a chilled water or condenser water system, the components of these systems are likewise sized to maintain design conditions, with one electrical switchboard removed from service. This level of redundancy can be obtained by either furnishing two sources of power to each air conditioning unit, or dividing the air conditioning equipment among multiple sources of power. The piping system or systems are dual path, whereby a failure of or maintenance to a section of pipe will not cause interruption of the air conditioning system. Alternative resources of water storage are to be considered when evaporative systems are in place for a tier 4 system.