Engaging the Development of Spatial Cognition Though Adpositional Play
Submitted to the Department of Architecture
in Partial Fulfillment of the Requirements for the Degree of
Master of Architecture
at the
Massachusetts Institute of Technology
January 2016

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LEARNING TOPOLOGY
Engaging the Development of Spatial Cognition Though Adpositional Play
by
Sixto Cordero Maisonet
Submitted to the Department of Architecture on
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This thesis was funded by the Marvin E. Goody Award
ACKNOWLEDGEMENTS

This Thesis was made possible with the support and counsel of my advisor Joel Lamere and my readers Brandon Clifford and John A. Ochsendorf.

I would also like to thank: my good friend Jorge Silén for his help completing elements of the final presentation, David Costanza for his guidance and his experience with roto-casting, and finally Eric Höweler and Meejin Yoon for lending me their Roto-molding machine.

I am grateful also to the Marvin E. Goody Award and its selection committee for making possible the prototyping and making explorations that composed an integral part of this thesis.

I would also like to thank Karen Kitayama, my partner, for her support and help throughout this thesis year. te amo.

This thesis is dedicated to my parents, Ivette Maisonet and Sixto Cordero, as well as my grandmother, Mercedes Quiñones. All three integral people in my intellectual development as a child. Without them none of this would have been possible.
ABSTRACT

This thesis establishes a qualitative analysis of current playground design and challenges the minimal role that playgrounds play in education, spatial cognition, and the development of a child’s understanding of space.

McDonalds’ playgrounds were introduced in the 1970s and proliferated across the nation (there are over 8,000 units). They created a model that has permeated American culture. This model is based on two paradigms: the creation of a totally risk-free world and a monolithic approach to playground design which relies on the “post and platform” construction model. Though this might be okay for a fast food pit stop, the user quickly loses interest. Historians attribute this design model to the loss of relevance of physical play. This thesis attempts to understand what playgrounds could be if the focus of the design shifts from one that prioritizes safety and ease of assembly to one that amplifies a child’s spatial experience and sensibility.

Models of learning through play are well documented and find their origin in the creation of the first kindergarten by Friedrich Froebel. However, these pedagogical tactics evolved separately from playgrounds and relied mostly on small toys that challenged children to understand and cultivate different areas of knowledge. Spatial cognition was rarely nurtured and broadly assumed to develop independently.

This thesis argues for the relevance of spatial cognition and grounds itself in the research of Jean Piaget, the father of developmental psychology. Through his research, Piaget outlined the different stages a child goes through to develop an understanding of space. I focus on the first stage, the topological stage, where children, lacking an understanding of geometry, understand the world through relationships of containment, location, direction, etc. This innate knowledge quickly disappears as a child grows and develops an understanding of the world in terms of its geometrical parameters.

The abstract grammatical particles that describe spatial or temporal relationships in almost every existing language are called adpositions. They describe in a topological manner the contextual relationships we have, or that we understand objects to have, with other objects. It is through the creation of spaces that expose children to a broad array of adpositional conditions that this thesis offers the developing child the possibility of learning through and about space by instrumentalizing his or her worldview.

Seeking a model that encourages participation and topological variability, this thesis proposes play spaces that inhabit a middle scale: mobile, modifiable objects that engage the child in different topological states depending on their position and orientation.

Thesis Advisor: Joel Lamere
Assistant Professor of Architecture
Jean Piaget, the father of developmental psychology, concluded through his research that children in early developmental stages have a topological understanding of space but lack an understanding of the geometrical distinctness of objects surrounding them, i.e. they understand the world through adpositional relationships. By instrumentalizing this theory, this thesis seeks to reformulate the role of the environment in a child’s development.

In analyzing the history of educational approaches for children it becomes apparent that, since its conception, objects have played a primary role in both didactic and ludic activates of developing children. However, more recent approaches, like the “Reggio Emilia”, advocate spatial specificity as a fundamental component for learning. Thus this thesis seeks to explore: how can architecture transform these tools creating environments through objects that integrate ludic and didactic activities and challenge children’s topological cosmology?

**Thesis Question**

**Key Terms**

**topology**- the study of homeomorphisms; i.e. spatial and geometric transformations that maintain constant relationships and connections

**environment**- surroundings or conditions, artificial or natural that a subject inhabits at a given time

**learning**- contextual act of acquiring, modifying or reinforcing, existing knowledge, behaviors, skills, values, or preferences through exposure to information, experiences or environments

**play**- recreational and participatory activity that requires the mental conception of a virtual world (magic circle) which has its own rules and conditions not bound by reality
## CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>title page</td>
<td>1</td>
</tr>
<tr>
<td>thesis committee</td>
<td>2</td>
</tr>
<tr>
<td>acknowledgements</td>
<td>4</td>
</tr>
<tr>
<td>abstract</td>
<td>5</td>
</tr>
<tr>
<td>thesis question</td>
<td>6</td>
</tr>
<tr>
<td>key terms</td>
<td>6</td>
</tr>
<tr>
<td>contents</td>
<td>7</td>
</tr>
<tr>
<td>the role of mcdonalds</td>
<td>8-9</td>
</tr>
<tr>
<td>places of learning</td>
<td>10-17</td>
</tr>
<tr>
<td>piaget &amp; topology</td>
<td>18-21</td>
</tr>
<tr>
<td>the role of adpositions</td>
<td>22-27</td>
</tr>
<tr>
<td>places of play</td>
<td>28-33</td>
</tr>
<tr>
<td>a child’s cosmology</td>
<td>34-37</td>
</tr>
<tr>
<td>design</td>
<td>38-61</td>
</tr>
<tr>
<td>rotocasting as a method of making</td>
<td>62-67</td>
</tr>
<tr>
<td>renders and location</td>
<td>68-73</td>
</tr>
<tr>
<td>prototypes</td>
<td>74-75</td>
</tr>
<tr>
<td>thesis defense</td>
<td>76-80</td>
</tr>
<tr>
<td>bibliography</td>
<td>81</td>
</tr>
</tbody>
</table>
THE ROLE OF MCDONALDS

Playground design in the United States has become a standardized commodity since the proliferation of McDonald playgrounds in the 1970’s and the development of soft play in 1983. Powered by an ease of construction and the promise of a risk free world the “post and platform” scheme (which characterizes these two models) became ubiquitous and transformed a highly promising programmatic challenge into a homogeneous selection of catalog prefabs.

This thesis as one of its primary drivers sought to challenge the post and platform model and attempt to understand its shortcomings, as well as the success of other play objects, such as Legos and videogames. The limitations of the former become quite apparent by comparison, while it offers a spatial experience this one is quite limited in its variability and the interaction with the object offers little agency when compared to videogames and almost no indeterminacy when compared to Legos and other modular toys. Consequently it is no surprise that many historians attribute the loss of relevance of physical play to the propagation of this model.

This thesis attempts to understand what playgrounds could be if the focus of the design is shifted from one that prioritizes safety and ease of assembly to one that amplifies a child’s spatial experience and sensibility.

(See Solomon, Susan. American Playgrounds: Revitalizing Community Space.)
The first PlayPlace with the familiar crawl-tube design with ball pits and slides was introduced in 1987 in the USA, with many more being constructed soon after. The original PlayPlace, however, was introduced in the 70’s and featured a simpler post and platform model. They are found in restaurants located in suburban areas or some big cities.

Legos, iPad and post and platform model examined in different criteria.
PLACES OF LEARNING

Models of learning through play are well documented and find their origin in the creation of the first kindergarten by Friedrich Froebel (1). However, these pedagogical tactics evolved completely separately from playgrounds and relied mostly on small toys that challenged children to understand and cultivate different areas of knowledge.

This thesis will research educational approaches to children’s early developmental stages, starting with the conception of the first kindergarten. By examining not only their curriculum but also their spatial and objectual characteristics, this thesis seeks to map out the topological relationships between these elements and its users and conceive a framework that through spatial objects generates didactical environments that teach trough play. These in part should be capable of supplanting educational toys for children in developmental stages.

Both my brief professional career, and my academic studies ground themselves heavily in the act of making. I have done and assisted in a large number of material installations and as of recent I have been developing and managing the construction of projects at full scale. This summer I will be fabricating my second professional project in close collaboration with my two partners and the Spanish office SelgasCano. This will be the second school we design and build for a low-income community in Kenya.

These projects do not only engage with material and budgetary limitations but also with how to generate and fabricate spaces that are apt for learning, through the reinvention of existing materials and construction techniques. My thesis seeks to explore these issues in depth. Through my research I have been investigating an array of educational methods, theories and objects for children in developmental stages, in order to understand the relationship between the actors at play. My goal is to instrumentalize this knowledge into a series of inhabitable spatial objects that reformulate play activities as didactical tools to teach children through experience.

Specifically the project looks at the manufacture of small scale structure using a hard system manufactured through the use of contemporary fabrication techniques. These spatial objects will radically depart from existing playground “kits” as they will create reconfigurable objects that are both movable and inhabitable by children bridging the gap between educational toys and architecture. This project seeks to address the physical challenges of weight, safety and assembly as well as the tasks laid out by the theoretical research it builds upon.

(1) See Frobel, Friedrich, and W. N. Hailmann. The Education of Man.
Froebel's views on education centered on the importance of play, games, and toys in the intellectual, spiritual, and social development of children.

Its philosophy and program was meant to serve as a transition between home and school, infancy and childhood.

It seeks to nurture and protect children, shielding them from outside influence in the same way one might protect a growing plant thus its name Kinder-Garten or literally, Children's Garden.

Froebel insisted that learning must start with the concrete and move to the more abstract, and that perceptual development preceded abstract thinking skills.

The program has been criticized for being far more structured than the loose, free-scheduled programs that would come to be advocated years later, and was a far cry from what we could consider a developmentally appropriate program today.
John Dewey, an American academic, was its most influential spokesperson. Dewey’s ideal school was one where children could grow physically, intellectually, and socially, as well as be challenged to think independently.

Progressive educators advocated methods of instruction that are based on individual interest, hands-on activities, acknowledgment of individual differences, and child-initiated activity whenever possible.

Uses Froebelian materials but put to use in different ways, children work through collaborative projects in small groups related to their own interests. "Whole-child" education is key to the progressive movement.

Dewey clarified that enjoyment and fun were not legitimate educational purposes, that educational activities always needed to support children’s learning and development.

The role of the teacher in a progressive education program to prepare children to be members of a democratic society. The curriculum would include “real experiences.”

Traditional education uses extrinsic motivation, such as grades and prizes. Progressive education is more likely to use intrinsic motivation, basing activities on the interests of the child. Praise may be discouraged as a motivator.
Maria Montessori founded the Casa dei Bambini, where she applied and experimented with methods she had initially designed for children with serious developmental delays on children without these cognitive issues.

Maria Montessori believed, based on her observations, that a child's intelligence was not fixed, that learning could be stimulated or stifled by the child's individual experiences, and that children learned best through their own direct sensory experiences of their world.

The Montessori approach centers on a child-sized classroom, full of specially designed and sequenced learning materials that were progressively complex. The teacher's role was not that of a teacher, but that of an observer and a guide, hence Montessori teachers are often referred to as directors.

The Montessori classroom is divided by 3 year age groups; 0-3, 3-6, and 6-12.

Children learn through experience, by observing and doing.

Children develop respect for each other and their classroom, placing items back on shelves before reaching for new ones. Their work is taken seriously, and not regarded as play.

Children are able to move about the room and are not rushed through an activity, but are expected to complete activities in-sequence.
Margaret McMillan and her sister Rachel McMillan were social reformers. Their main focus was improving the lives of the "slum child."

They advocated for school meals and opened the Open-Air Nursery School and Training Centre in London, which was attended by 30 children between 18 months and 7 years old.

A play-oriented, open-air environment was born out of their response to health problems they were witnessing in poor communities and was meant to be a model for other schools as well as a training center for future and current teachers. They called their model "nursery schools"

"The role of the school is to keep the paths of exploration open so children can develop in their own unique ways."

Daily schedules are generally large blocks of time where children are free to choose their activities. Classrooms are divided by area, with spaces for block construction, dramatic play, arts and crafts, sand and water tables, science centers, math centers, and language centers.

The teacher's role is to facilitate an environment that fosters learning, supports the child's emotional development, social development, and provides children with the tools they need to explore and experience their environment.
Founded by Rudolf Steiner, the Waldorf Astoria Schools were created to serve the children of the workers employed in the Waldorf Astoria Cigarette factory. These schools were designed to promote healthy, unhurried opportunities for learning based on an individual child's stage in development. Steiner stressed the development of the child's body, mind, and spirit.

Like other programs, the focus was on educating the 'whole' child, because Steiner believed that engaging a variety of academic, artistic, and handicraft subject areas would equalize the human aptitude for thinking, feeling, and will.

The curriculum consists of storytelling, puppetry, arts and crafts, imaginative play, and practical work like knitting, gardening, cleaning, and baking.

Classrooms settings were designed as an extension of home. They featured soft colors, natural materials, and simple, homemade toys made from cloth and wood (no plastic, battery operated toys), that encouraged imaginative play.

Teachers in Waldorf programs stay with their groups of students for three years, allowing teachers to offer continuity, build trust and relationships, and build a community within their classroom.

The focus in the Waldorf classroom is on sensory exploration and self-discovery rather than formal instruction and merit, helping children develop a sense of compassion and responsibility.
Conceived by an educational innovator named Loris Malaguzzi, the director of the school in collaboration with the parents that funded its creation.

By 1963, the single school had become a government-funded system of Early Childhood programs throughout Italy. By the 1980’s and to this day, educators from all over the world visit the Reggio Emilia to observe their methods.

The philosophies key concepts are that children are strong and competent individuals with the right to the best education available, that education is based on relationships, and that education is based on the interaction of children working and playing together in small groups.

The Reggio approach fosters intellectual development through a focus on symbolic representation. The primary curriculum is in-depth project work based on the interests of the children. Children are encouraged to express themselves through ‘natural languages’, including drawing, painting, working in clay, sculpting, constructing, conversing, and dramatic play.

The environment is equally important, referred to as ‘the third teacher’, because of how children construct knowledge by their interactions with said environment. The classroom is set up to promote partnerships, social interaction, and constructive learning. Key elements of the classroom include the atelier (art studio), and the piazza (central gathering area).
Carl Theodor Sørensen, a Danish modernist landscape architect, noticed that children preferred to play everywhere but in the playgrounds that he built.

In 1931, he imagined "A junk playground in which children could create and shape, dream and imagine a reality." In a way similar to a child’s experience in the country.

Sørensen believed "children’s playgrounds are the city’s most important form of public plantation". He believed children needed sun and open space to play in and hated the trend for dark, shady courtyards as play spaces.

These "junk playgrounds." propagated quickly both in Europe and England.

Currently, about 1,000 adventure playgrounds exist in Europe, largely in Denmark, Switzerland, France, Germany, The Netherlands, and in England. In Germany alone there are some 400 adventure playgrounds. Japan has a significant number of adventure playgrounds as well.
PIAGET & TOPOLOGY

This thesis advocates for a different conception of spatial play and grounds itself in the research of Jean Piaget, the Father of developmental psychology. Through his research, Piaget outlined the different stages a child goes through to develop an understanding of space. The first one being a topological stage, where children, lacking an understanding of geometry, understand the world through relationships of containment, location, direction etc. This innate knowledge quickly disappears as a child grows and develops an understanding of the world in terms of its geometrical parameters. The diagrams on the top on the next page are the result of Piaget's experiments. In these you can observe, as he concluded, that children have a basic understanding of the world in terms of its topology, as they are able to replicate the topological elements presented to them while ignoring the geometrical specificities that might be the focus of our attention.

To understand the scope of this thesis it is necessary to clarify what Piaget defines as topology and its differences with the mathematical original term. In their reading of *A Child's Conception of Space*, translators F.J. Langdon and J.L. Luzner unpack the term as the study of homeomorphisms; i.e. spatial and geometric transformations that maintain constant relationships and connections. Mathematicians however, often narrow the scope of topology to the study and analysis of the internal relationships of an object. While Piaget's claims are very much aligned with this traditional definition of topology, if we examine the images resulted from his experiments, especially those from the earlier stages we see blending or continuity between the objects depicted, i.e. a representation that forgoes the distinctness of the trees and the mountain (labeled as Sub-stage 1A on next page.) (2).

Additionally in evaluating the further stages of development, the distinctness between the mountain and the objects that occupy it begin to appear in the form of lines. However, there is also a constant recognition of what is up or down in relationship to the surface of the mountain, e.g. the house is consistently placed not only connected to the mountain, but consistently with its correct top side up. These conditions of which topology would find ambiguous represent in themselves a departure from a mathematical understanding of the term. Thus both Piaget's definition and this thesis' definition of topology include to a degree the recognition of the context or environment and depart from the mathematical understanding of the term.

In a way, the definition of topology which this thesis seeks to explore is not one that studies the internal relationships of a fixed and externally observed system, but rather of one that is experienced through direct perception and participation. In the closing statements on *A Child's Conception of Space*, Piaget affirms, “Topological relations are relations, which remain purely internal to each object or pattern. On the other hand, Euclidean relations, completed by the construction of reference frames, are essentially relations established between numbers of objects or patterns”. This statement and the recognition of flexibility between the stages of development, reaffirm that children in developmental stages do have a topological cosmology that they complement with a developing appreciation for the Euclidean relationships of their surroundings. Thus the definition of a “topological conception of space” as defined in developmental psychology diverges from the mathematical definition of topology, as it is not a fixed one but one rolled by a growing understanding of the child. Considering this allows for the consideration of didactic spatial objects that can transform and present children with distinct learning opportunities unabridged by spatial preconceptions.

(2) See Piaget, Jean and Barbel Inhelder. and Alina Szeminska. *The Child's Conception of Space*
Metro maps are a great example of topologically accurate and geometrically inaccurate representations as they ignore distance and specificity in order to clarify connectedness.
This entails that children below the age of six possess a different type of perception not bound by many constraints of geometry. It is in this notion where the possibility of reformulating the spatial exposure of small children comes into play. While diverse in shape and color these playgrounds are topologically the same.

These diagrams depict topologically equivalent shapes that have distinct geometries.

Children relate to their environment in an adpositional manner understanding objects through the relationships they have with them.
THE ROLE OF ADPOSITIONS

“Text constitute lexical forms that are conventionally paired with meanings.”

The abstract grammatical particles that describe spatial or temporal relationships in almost every existing language are called adpositions. They describe in a topological manner the contextual relationships we have, or we understand objects to have, with other objects. It is through the creation of spaces that expose children to a broad array of adpositional conditions that this thesis offers the developing child the possibility of learning through and about space by instrumentalizing his or her worldview.

Adpositions originate from encoded spatial relations between two physical entities. In their study (3), Tyler and Evans, argue that all meanings of grammatical adpositions are systematically grounded in the nature of human spatio-physical experience. As they express “The original ‘spatial scenes’ provide the foundation for the extension of meaning from the spatial to the more abstract.”

Prepositions and postpositions, collectively called adpositions, are grammatical particles that describe spatial or temporal relations in the sentence structure of almost every existing language. They describe in an experientially topological manner the contextual relationships we have, or we understand objects to have, with other objects, in either spatial or temporal terms. This condition allows the study of grammatical adpositions to be foreground as the start of a reverse engineered topological lesson for children. It is by the unpacking of these grammatically pure structures that we will find sequences of experiential topology that offer the developing child the possibility of learning through space.

Piaget’s stage theory relates how children become progressively detached from the world of concrete objects and local contingencies, gradually becoming able to mentally manipulate symbolic objects within a realm of hypothetical worlds. Seeking a model that encourages participation and topological variability, this thesis proposes play spaces that inhabit a middle scale; movable modifiable objects that engage the child in different topological states depending on their position and orientation.

Spatial properties include location, size, distance, direction, separation and connection, shape, pattern, and movement.
above
aboard
across
against
along
amid
among
around
at
behind
below
beneath
beside
between
beyond
by
in front of
inside
near
off
on
under
underneath
upon
within
outside
over
past
through
toward

i am ___________ this object(s)
static prepositions

inside- implies inhabiting the interiority of an object within
outside- implies exteriority from an enclosed space
on- necessitates a xy plane of reference
upon - implies direct contact on the top side of the plane
beside- implies inhabiting a location next to an object by
under- necessitates a xy plane of reference
underneath - implies direct contact on the bottom side of the plane
at- deonotes a distinct location
below- necessitates an xy plane of reference
beneath - ambiguous on contact
above- necessitates a xy plane of reference and inhabiting the space above
- ambiguous on contact
in front of- implies cardinal directionality (front, back, left & right)
- the location of the subject is on the most visible side of the object
behind- implies cardinal directionality (front, back, left & right)
- the location of the subject is on the less visible side of the object
amid- Implies the subject is surrounded by a series of objects among
between- implies the subject is lateraly surrounded by two or more objects
near- the subject is located close to the object
- the subject is not on direct contact with the object

translation prepositions

through- implies the movement of a subject traversing an object
along- implies the movement of a subject parallel to an object
across- implies the movement of a subject passing by an object
aboard- denotes a relationship of inhabiting a moving object
against- implies the movement of a subject applying force against an object
toward- implies the movement of a subject in the direction to meet an object
around- implies the movement of a subject circling an object
beyond- implies the movement of a subject past an object
off- implies the movement of a subject from a object to its exterior
past- implies the movement of a subject after translating by an object
distinct modes of topological inhabitation
children actively contribute to the construction of their knowledge, by transforming their world. even mundane objects and experiences represent possibilities for learning and play.
PLACES OF PLAY

Ultimately this thesis had three goals,

to qualify existing playgrounds and their spatial value from a child’s point of view

to incorporate elements of agency and indeterminacy in spatial play

to create a play space that possesses topological variability and challenged a child’s spatial awareness

This section addresses the first of this goals. This thesis explored existing playgrounds and their topological configurations as a way of assessing their level on spatial engagement with their users. The value of this places as learning spaces directly relates to the spatial opportunities they provide for the children.
mcdonald's play place
swing time [haweler yoon]

ping pong [mitsuru senda]
atlanta piedmont park [isamu noguchi]
logis du clapet [group ludic]

rocking beauty hobby horse [gloria caranica]
the lady of the lake [pierrr szekely]

netplayworks [toshiko horiuchi]
A CHILD’S COSMOLOGY

Our culture often sees children as incomplete or disabled adults, a misconception that has shaped most of the spatial toys children are exposed to. Mini houses, cars and tiny kitchens whose underlying purpose is to train children to overcome their “disability” and have them conform to the rules of our society.

This thesis aims to change this model. The objects proposed will aim to develop a child’s abstract understanding of space, while encouraging a spatial appreciation and a curiosity for spatial based play. This thesis advocates for toys and spaces that do not attempt to tell children what they can be or do but allows them to come up with this themselves. To Piaget, cognitive development is a progressive reorganization of mental processes that results from biological maturation and environmental experience. Piaget proposed that children construct an understanding of the world around them, experience discrepancies between what they already know and what they discover in their environment, and subsequently adjust their ideas accordingly. This thesis proposes to embrace this theory and replace the current paradigm.

erroneous conception of children as incomplete adults

children having a distinct cosmology diagram
toys based on the conception that children are adults in training
an adult's perception of a child
DESIGN

Based on the parameters stated before, the design attempts to engage the user with a shrink-wrapped space that addresses most of the adpositional relationships outlined in the English language. Hopefully this evokes and permits a wide diversity of possibilities in terms of spatial play.

The design is also modular and through its geometry it can be aggregated in a wide array of topological conditions. The following pages outline, through sectional cuts, the possible topologies according to the different possible positions the module can stand in.
TOP- all possible positions of the module

NEXT PAGES (40-59): adpositional topologies of the module
through
against
behind
above
aboard
beneath
outside
over
around
in front of

behind
past
The project is capable of simulating complex topological experiences in which a Klein bottle’s perceptual effect is replicated.
inhabited section
ROTOCASTING AS A METHOD OF MAKING

Rotocasting is a manufacturing method that uses self-curing resins in an unheated mold, using slow rotational speeds powered by servos in a machine that provides movement in at least two axis of rotation.

After analyzing various physical limitations children have, a series of parameters were determined that would limit the shape, weight, scale and general dimensions of the final object. These dimensions guided the design of openings, spaces and wall thickness of the object. Due to the limitations set by these parameters and in the interest of creating an object that resisted a multiplicity of possible vector loads, roto-casting was selected as the primary method of making.

Once this method was selected, after the initial assessment, a series of manufacturing parameters came into play. Some of which are listed and described below. (5)

Draft angles
The draft angle is the degree of taper of a side wall or rib needed to allow the molded plastic part to be removed from the mold. Without proper draft, plastic parts may be difficult or impossible to remove from the mold after casting. Rotocasted parts usually require a draft angle of 5 degrees in all directions.

Undercut
Undercut is a manufacturing limitation that is present in various stages of the manufacturing process. In this particular case it was present in the machining and in the molding, Undercut is, in machining, any surface that cannot be directly milled by the end mill cutter due to its position in reference to the angle and axis of cut. In molding, undercut is any indentation or protrusion in a shape that will prevent its withdrawal from a mold. Undercuts can still be molded, but require a side action or side pull piece. This is an extra part of the mold that moves separately from the other components making the release of the undercut possible. This project created a 12 part mold that allowed for a completely undercut free part in both processes.

Wall Thickness
Wall thickness refers to the dimension of a wall in a hollow object. In rotocasting this dimension in directly related to the amount of liquid material inserted into the mold and the speeds of rotation of the two axis of the rotocasting machine as well as the geometry of the mold. If the geometry is longer on one axis than the other the speed of rotation needs to compensate this fact in order to maintain a consistent wall thickness.
Roto-casting offers a seamless hollow object that can have a wall thickness of under 1/16 of an inch permitting the creation of a light-weight spatial structure.

ages 4-7 physical limitations/ergonomics

- **Age: 4 years**
  - Shoulder width: 10”
  - Weight: 40 pounds
  - Carrying capacity: 8 lbs

- **Age: 5 years**
  - Shoulder width: 11”
  - Weight: 45 pounds
  - Carrying capacity: 9 lbs

- **Age: 6 years**
  - Shoulder width: 12”
  - Weight: 50 pounds
  - Carrying capacity: 10 lbs

- **Age: 7 years**
  - Shoulder width: 12”
  - Weight: 55 pounds
  - Carrying capacity: 11 lbs
collaborative play

maximize interior space // resist external forces

guiding parameters
rotocasting process diagram from left/top to right/bottom
rotocasting machine diagram
Höweler + Yoon's 21"x34" rotocasting machine
RENDERS AND LOCATIONS

One module and a single base in a single family house. [home]
five modules in a shopping mall.
Three modules in Central Park. [park]
Four modules in Times Square. [city]
Five modules in a rural environment. [rural]
One module in the Lawn of D. [urban park]
PROTOTYPES

3d printed flexible nylon modules [2]
Rotocasted prototype made using 65D smoothen
THESIS DEFENSE

diagram of thesis layout


