99A012I

Project Number: 43-DVG-7845

99A012I

TURF INJURIES

An Interactive Qualifying Project Report

submitted to the Faculty

of the

WORCESTER POLYTECHNIC INSTITUE

in partial fulfillment of the requirements for the

Degree of Bachelor of Science

By

Adam M. Alderson

James Cairns

Michael Tarasiewicz

Date: October 8, 1999

Approved:

Professor Daniel G. Gibson III, Advisor

Abstract

This report addresses the question, "Is artificial turf injuring athletes?" The perception that artificial turf causes more injuries than natural grass is explored in depth through examining current articles and studies on the topic, coupled with interviews, inquiries, questionnaires, and site visits. We concentrated on football because that sport provided the most data and the highest injury rate in collegiate sports. We conclude that WPI's new AstroTurf playing field is safer than the previous artificial turf surface, and that grass is possibly marginally safer, but with higher maintenance costs and with limited year-round usage.

Acknowledgements

We would like to acknowledge these companies, and their employees we had contact with, for their aid in our data research:

AstorTurf Synthetic Turf Systems

FieldTurf - John Gilman, CEO

SafTurf International, Inc. - John Chaplin, Sales Representative

Grass-Tex, Inc - Bucky McCamy, Sales Representative

We would also like to thank the following people for their contributions to this report:

Dr. Daniel G. Gibson III, Assistant Professor of Biology

Dave Abraham, WPI Head Athletic Trainer

Chris Robertson, WPI Assistant Football Coach

Dennis Bruck, WPI Assistant Football Coach

Tim Smith, WPI Assistant Football Coach

Jeff Lane, Physical Education Instructor

TABLE OF CONTENTS

List of Tables

List of Illustrations

INTRODUCTION

It is all around us. You can find it on city playgrounds and even in some city parks. It can be seen at high schools and colleges all over the United States. You can see it on athletic fields all around the world. What is this "it" we are referring to? This "it" is artificial turf. Why is it appearing all around the world? Some wonder about its possible uses, but what we really want to know about artificial turf is: *"Is It Injuring Our Athletes?"*

More and more, institutions are using artificial turf as a playing surface for all types of sports activities. They feel that they have good reasons for using artificial turf instead of grass. Stated justifications are that artificial turf is more durable, more cost effective, and just as safe as grass. While its durability is a fact and its cost is debatable, whether there is parity in safety between grass and artificial turf is uncertain. There have been conflicting reports pertaining to the safety of grass vs. artificial turf. Reasons for these many conflicts include the testing agency, size and speed of the athletes, conditions of the field in use (wet, dry, etc.), and the type of shoe and other equipment used on the surface.

Our hopes are that our research will answer the safety issues and benefit institutions in their quest to choose the best type of athletic field. We are looking to determine this by seeing what manufacturers are doing to improve performance in injury reduction with their new synthetic turfs that are being introduced today. We will also look into studies that pertain to injury occurrence with athletes on each type of playing surface as well as the properties of different types of artificial turf surfaces. Another part of our research will deal with which of the two options is most cost effective. We will try

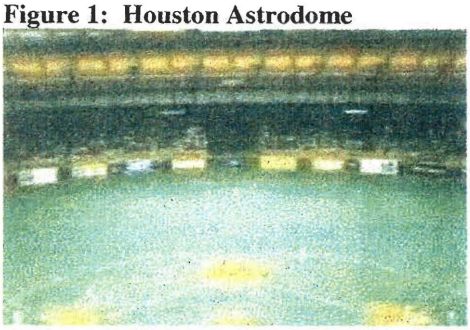
to determine if there is a trade-off between maintenance costs and injuries or whether one type of playing surface is clearly superior.

Artificial turf is a grass-like surface used to replace grass fields. Artificial turf is a textile product whose composition varies with each producer. The materials are sewn and woven into a type of carpet. The basic component, "fiber ribbons", are thin extruded polymers, which are set at different lengths depending once again on the producer's intended use. Underneath the ribbons, a layer of shock absorbent material is provided. This material changes based on the producer, turf type, and customer preference. Synthetic turf has many different uses and can be found in use as a playing surface, as a miniature golf course, carpets, and even as doormats to name a few. Our research will be dealing with playing surfaces and sports such as football.

The original need for artificial turf was in inner cities, to give kids there a better playing surface. This need was brought forward by research by the Ford Foundation on children's military health records, the only extensive material on the subject, the Ford Foundation found that "kids from small towns and the country were swifter, stronger, and had more endurance than their counter parts from cities and urban areas" (AstroTurf Historical Web Page). They determined this difference had to do with where and how these children were exercising and playing. Those children in rural areas had more space to play and therefore got more and better exercise as opposed to children in cities who were stuck with smaller, paved playgrounds. At that same time, a subsidiary of Monsanto, Chemstrand, was creating synthetic fibers for carpeting in places such as schools. Therefore, the Ford Foundation asked Monsanto, a synthetic fiber company, to develop some kind of surface for these inner city kids to play on.

The challenge was to develop a material to withstand heavy city usage and pollution, but to require little maintenance as possible. Monsanto researched many different materials and their properties (i.e. flammability, toxicity, and safety for falling on). Their finished product was first installed in 1964 in the field house of the Moses Brown School in Providence, Rhode Island. This original product managed to last for 25 years before being replaced (AstroTurf Historical Web Page).

Figure 1: Houston Astrodome



After installing their new product in some playgrounds in New York City, the Monsanto Company was confronted with their next challenge. This challenge was to create a playing surface to be used in the newly built Houston Astrodome. The Astrodome had been built in 1965 by Judge Roy Hotheinz to be used by the Houston Astros major league baseball team. A picture of this stadium can be seen above in Figure 1. It was originally constructed with a clear plastic roof so that it would be possible to grow grass inside. However, players complained about the glare that resulted from the clear roof during day games. Part of the roof was then painted over to reduce the glare. This eliminated too much sunlight to allow natural grass to grow. Therefore, Judge Hotheinz contacted the Monsanto Company and challenged them to produce a large-scale synthetic playing surface. Within a year Monsanto had successfully completed the installation of the synthetic surface, which was named "AstroTurf". The surface was more than 125,000 square feet in area and the pieces were seamed together with more than tree miles of zippers. The dirt floor

was kept in place underneath the turf, which meant that the turf could be removed so those events such as rodeos could take place in the Astrodome.

Following the success of AstroTurf, its usage began to spread. In 1967, two outdoor facilities were built with AstroTurf as its surface. These first outdoor stadiums to be surfaced with artificial turf were Indiana State University and Seattle Memorial Stadium. The popularity of artificial turf continued to grow as other manufacturers began to produce their own types of turf to compete with Monsanto. For example, 3M came out with "Tartan Turf", American Biltrite Rubber Company created "PolyTurf" and SuperTurf created a self-named product. This was the beginning of a large industry.

Timeline

We have briefly described the early history of artificial turf. What follows is a time line of important events in the evolution of artificial turf:

1962

- Educational Facilities Lab, a Ford Foundation agency, calls for synthetic playing surfaces to improve fitness of city kids. Chemstrand Company (later Monsanto Textiles Company) Creative Products Group accepts the challenge and begins research. *

1964

- "Chemgrass" playing surface installed by Chemstrand in a fieldhouse at Moses Brown School, Providence, RI. *

1965

- "Chemgrass" installed on playground in Central Park, New Your City, and on rooftop at PS 45, Brooklyn, NY. *
- Harris County Sports Authority opens the "Astrodome" in Houston, TX, billing it the "Eighth Wonder of the World". As a domed sports stadium, the playing surface was to be natural grass. *
- Astrodome roof painted to control glare during day games. Grass dies due to insufficient sunlight. *

1966

- Newly renamed "AstroTurf" installed on infield of Astrodome before opening day of 1966 baseball season. *
- Complete baseball field installed using AstroTurf surface at All-Star break. *
- Complete football field installed in Astrodome for AFL Houston Oilers for 1966 football season. *

1967

- First outdoor university to have a synthetic turf football field completed at Indiana State University, Terre Haute, IN, on September 10. AstroTurf is chosen. *
- First outdoor high school synthetic turf football field completed in Seattle Memorial Stadium, Seattle, WA, on September 15. AstroTurf is the surface. *
- 3M enters the picture when they install their product, Tartan Turf, on a practice field at the University of Minnesota. #

1968

- Fieldhouse at Adams State College, Alamosa, CO surfaced with AstroTurf as high altitude training site before 1968 Mexico City Olympic Games. *
- First knitted AstroTurf field installed at Thomas Field, a University of Alabama practice facility. This was also first football field to use a closed cell underpad. *
- Basic patents on "synthetic grasslike playing surfaces" issued to Wright and Faria, of Monsanto. *

1969

- Baseball infield installed in Comiskey Park, home of Chicago White Sox baseball team. First major league outdoor baseball stadium. *
- Alabama adds Denny Stadium to the AstroTurf list. First major university to install synthetic turf on both its practice field and main stadium. *
- Football game for national championship played between Universities of Texas and Arkansas on AstroTurf surface in Razorback Stadium, Fayetteville, AR. *

1970

- Sport Install, Inc. organized as a wholly owned Monsanto subsidiary corporation for the nationwide and international installation of synthetic turf playing fields. *
- AstroTurf surface in fieldhouse at Sportschule Hennef, Germany is first installation in Europe. *
- American Biltrite Rubber Company installs "PolyTurf" in Orange Bowl, Miami, Florida. *

- First World Series games on synthetic turf in Riverfront Stadium, Cincinnati, with new AstroTurf surface. *

1971

- Ivor Wynne Stadium, Hamilton, Ontario is first AstroTurf field in Canada. *
- Caledonian Park, Islington, London, England, first AstroTurf field in the UK, is used for 1200 soccer games per year. *

1972

- PolyTurf in Orange Bowl, made of poorly stabilized polypropylene fails due to ultraviolet degradation, and is replaced. *

1973

- First AstroTurf surfaces installed in Algeria and France. *
- The Consumer Products Safety Act established the Consumer Products Safety Commission (CPSC). One of the first petitions comes from the National Football League Players Association (NFLPA), seeking to have artificial turf declared a "banned hazardous product". The petition was rejected. *

1974

- NFL Super Bowl played on AstroTurf in Rice Stadium, Houston, TX. *
- Mitsubishi Heavy Industries Sports Club, Chofu, Tokyo is first installation of AstroTurf surface in Japan. *
- Artificial turf found "not a health hazard to professional football players" by NFL Management Council study, following extensive epidemiological project of Stanford Research Institute ("SRI, Inc.") and review by committee headed by Dr. Bill McColl, former Chicago Bear end and member of NFL Hall of Fame. *

1975

- Spartak sports center, Moscow, Russia is first AstroTurf installation in USSR. *
- Aloha Stadium, Honolulu, is first AstroTurf stadium in Hawaii. *
- Sugamo Sports Club, Tokyo, is second AstroTurf installation in Japan. AstroTurf installed in Riyadh, Saudi Arabia in spite of Arab League blacklist. *
- 3M withdraws Tartan Turf from the market, and American Biltrite withdraws PolyTurf. *
- Poligras installed in Valhalla Stadium, Gothenburg, Sweden, by J.F. Adolff, of West Germany. *
- NFLPA refiles petition with claims of new evidence. The petition is once again rejected. *

1976

- Molson Stadium, McGill University is site for 1976 Olympic Games field hockey competition. International Hockey Federation (FIH) recommends synthetic turf for all international level competition. *
- Synthetic turf found "not a hazardous consumer product" by US Consumer Products Safety Commission in finding CP 76-12. *
- NFLPA submits third petition. After extensive studies, the petition is denied once again. *

1977

- AstroTurf surface with heated subbase and vertical drainage system installed in Jordahl Stadium, Oslo, Norway. *

1978

- First AstroTurf soccer system installed in Leeds, England as part of major research program on soccer surfaces. *
- Heated, drain-through AstroTurf system installed in Stavanger, Norway. *
- Midwood High School, Brooklyn, NY, is first New York City high school stadium to receive an AstroTurf surface. *
- FieldTurf begins research and development on new possible technologies relating to artificial turf. †

1979

- Western Australia Hockey Association, Perth, receives first Australian AstroTurf hockey pitch. *
- Baldrich Park, San Juan, Puerto Rico has AstroTurf hockey/soccer surface installed for Pan-American Games hockey competition. *
- Bergen, Norway is northernmost AstroTurf location. *
- AstroTurf surface at Hockey Club of Pakistan, Karachi is first synthetic turf installation in Pakistan. *

1980

- AstroTurf surface installed on soccer stadium in Garoua, Cameroon, and at Wagener Stadium, "the Mecca of hockey" in Amstelveen, Holland. *
- AstroTurf surface at Obras Sanitarias hockey field, Buenos Aires, is first synthetic turf installation in Argentina. *
- All-Pro, Inc. organized by former SuperTurf employees. *

- First all synthetic turf World Series played between Philadelphia (AstroTurf in Veterans Stadium) and Kansas City (Tartan Turf in Royals Park). Philadelphia wins. *
- PoliGras found to be infringing AstroTurf patents by Royal Civil Courts, UK. *

1981

- "Texas Turf", first textured AstroTurf system, installed in Texas Stadium, Irving, Texas, for Dallas Cowboys. *
- Union College, Schenectady, NY is first to receive AstroTurf-8 installation. *

1982

- Briggs Cage, Harvard University is first AstroTurf "Magic Carpet" installation. Monsanto applies for patents on the new conversion system *
- Mulcahy Field, Anchorage, Alaska is northernmost outdoor US AstroTurf playing field. *
- Professor Roskam recommends sand filled turf systems in speech at Cologne SBN trade show. Sand filled fields become popular in Holland. *

1983

- Texturing process adopted as standard for all AstroTurf surface pile fibers. *
- Commune of Jokkmok, Sweden, receives first AstroTurf installation north of the Arctic Circle. *
- Trenton State College, New Jersey, and Hinchcliffe Stadium, Paterson, NJ are sites for first vertical draining AstroTurf 8 installations in USA. *

1984

- Queensmead, Durban, South Africa, receives first AstroTurf hockey field in that country. *
- En-tout-cas sand filled turf system installed on intramural field at Georgia Tech (First sand-filled installation in USA). *
- "OmniTurf" sand filled system installed at Pelican Park, a softball complex in Lafayette, LA. *

1985

- Super Turf withdraws from synthetic turf business in bankruptcy. *
- First "OmniTurf" football fields installed at the University of Missouri and James Madison University. #
- Worcester Polytechnic Institute installs "OmniTurf" to fill the need for a multi-purpose field. #

1987

- Hubert H. Humphrey MetroDome, Minneapolis, receives AstroTurf 8 surface, making AstroTurf the surface of choice for all Major League Baseball parks having synthetic turf. *
- Crest-Nicholson exits synthetic turf business in North America, selling All-Pro, Inc. to TecSyn (Canada), producers of "OmniTurf". *

1988

- Balsam AG acquires AstroTurf Industries, Inc. in stock purchase transaction. AstroTurf organization remains intact. *
- AstroTurf Industries, Inc. celebrates 20th anniversary of Dalton, GA, plant operations. 14 twenty year veterans honored on opening night at new AstroTurf "Magic Carpet" installation in Astrodome. *

1989

- All-Pro and OmniTurf organizations acquired by Balsam from TecSyn. *
- AstroTurf Industries, Inc. celebrates 25 years of synthetic turf with ceremonies at site of initial installation in Moses Brown School, Providence, RI. Some of the turf from original installation is still in use. *
- AstroTurf installs synthetic turf on "Elastic Layer" (poured in place) subbase/cushion system at The College of William and Mary and on Kleeberger Field, University of California, Berkeley. *

1990

- StadiaTurf formed by former employees of All-Pro and OmniTurf. *
- Balsam USA introduces "Polynit" knitted polyolefin surface for lighter duty installations. *

1991

- New York high school fields with AstroTurf surfaces pass the 20-year mark. *

1992

- AstroTurf surfaces installed using patented "Action Bac" dimensionally stabilized backing systems over elastic layer subbase/cushion systems. (AstroTurf Europa system). *
- First AstroTurf "Magic Carpet" in Europe installed in Jyvaskila, Finland. *

1994

- German management of Balsam AG indicted on charges of financial mismanagement. Massive evidence of fraud uncovered. Original American AstroTurf group is not involved, and remains intact. *
- AstroTurf Industries, Inc. asks for bankruptcy protection from Federal Bankruptcy Court to protect its organization and asset base from German banks. *
- First AstroGrass soccer pitch installed at Leikner Football Club in Reykjavik, Iceland. *
- FieldTurf installs its first playing field (soccer) in Ancaster, Ontario, Canada. †

1995

- AstroTurf Industries, Inc. Acquired by Southwest Recreational Industries, Inc., and renamed AstroTurf Manufacturing Company, Inc. Other parts of Balsam AG (German organization) broken up, divided mainly between Desso/DLW of Germany and Netherlands, Polytan, Germany, and ETC Group (UK). ETC acquires Balsam Pacific. *

1996

- Following unacceptable performance by Korean and newly organized American turf supplier, Atlanta Committee for the Olympic Games awards 1996 Olympic Games Field Hockey Facilities contract to SWRI/AstroTurf organization. AstroTurf pitches installed in record time, and reported to be the best hockey pitches ever inspected by FIH approved testing laboratory. *
- First US made AstroGrass pitch installed at Sir Thomas Picton School, Wales. Others installed in Greece and Canada. *
- FieldTurf installs its first playing field (soccer) in the United States in Springfield, Oregon. †

1997

- AstroTurf Magic Carpet installed at Osaka Nankei Dome. First "Magic Carpet" installation in Japan. *
- AstroTurf loop pile surface developed for baseball warning tracks, and approved by Major League Baseball. *
- AstroTurf 12 introduced, taking advantage of newly developed proprietary stabilization technology (patents applied for) to permit softer, less abrasive more "comfortable" turf system with improved moisture retention properties. *
- SprinTurf installs its first playing surface in Canton, Ohio near the Football Hall of Fame. ‡

1998

- AstroGrass pitches replace conventional sand-filled turf installations in UK, Ireland and Holland, including Sutton Park (England), Pinoke Club (Netherlands), Isle of Man (UK), and Hurly Hockey Club (Netherlands). First three AstroGrass pitches installed in South Africa. *
- SWRI introduces "AstroPlay" sand/rubber composite infill soccer turf system at Town and Country Soccer Complex outside Cincinnati, OH. Second AstroPlay field installed for American football and soccer at University in Wichita, KS. *

1999

- FieldTurf installs the artificial turf of the same name in the football stadium of the University of Nebraska. †

* = AstroTurf Historical Web Page
† = FieldTurf Web Site
# = 1995 WPI Football Engineers Media Guide
+ = Keene et al. Tartan Turf® on trial – The American Journal of Sports Medicine, 1980
‡ = Pressley Associates Turf Report for North Kingstown High School, 1998

CURRENT PRODUCTION

As seen in the timeline, artificial turf has a very rich history and it has become an important factor in the world of sports as well as other things such as playgrounds and doormats. The timeline shows that Monsanto created and installed the first artificial turf called "Chemgrass" in 1964. This synthetic grass was later termed "AstroTurf" as previously mentioned. The creation of this "fake grass" quickly became a large moneymaker once word got around of its existence and its low maintenance, numerous companies began to join in on the production and sale of it.

By 1967, AstroTurf could already be found in outdoor stadiums as well as indoor. They appeared to have a monopoly in the synthetic turf market until 3M came out with their turf, "Tartan Turf". They installed it in three colleges in 1968 and competition began. In the late 1960's and all through the 1970's, numerous competitors were fighting for their niche in the market. For example, American Biltrite Rubber Company came out with "PolyTurf" in 1969 and SuperTurf International had "SuperTurf" in 1976 as well as "WycoTurf", "DurraTurf", and others that came later. In 1971, AstroTurf went international when they installed a soccer field at Caledonian Park in the London Borough of Islington and a field house at Sportschule Hennef in Germany. This brought about a realization to producers that there is a market for artificial turf, conceivably, all over the world. Competition became international when Germany's J.F. Adolff AG brought about "PoliGras". A few other companies followed from Japan and Korea as well as the UK. All of these companies have brought about a variety of names for artificial turfs such as "Cam Turf", "Instant Turf", "Stadia Turf", "OmniTurf", "Kureha", and "DLW". From all of this competition, AstroTurf remained the regular number one

choice among customers. Many of the companies that tried to compete with AstroTurf have since dropped their production of artificial turf as 3M and American Biltrite did in 1975 or have since gone out of business.

Since 1975, when the first major international tournament, "8-Nations" field hockey tournament, was played on artificial turf, it has become a lot more visible. Artificial turf has been used in the 1976 Olympic field hockey event and even more recently in the 1992 and 1996 Olympic Summer Games for field hockey and other events. Artificial turf has also been used numerous times in other large events such as the SuperBowl, and the World Series in baseball. Today there are thousands of artificial turf fields being used all over the world for many different sports and activities.

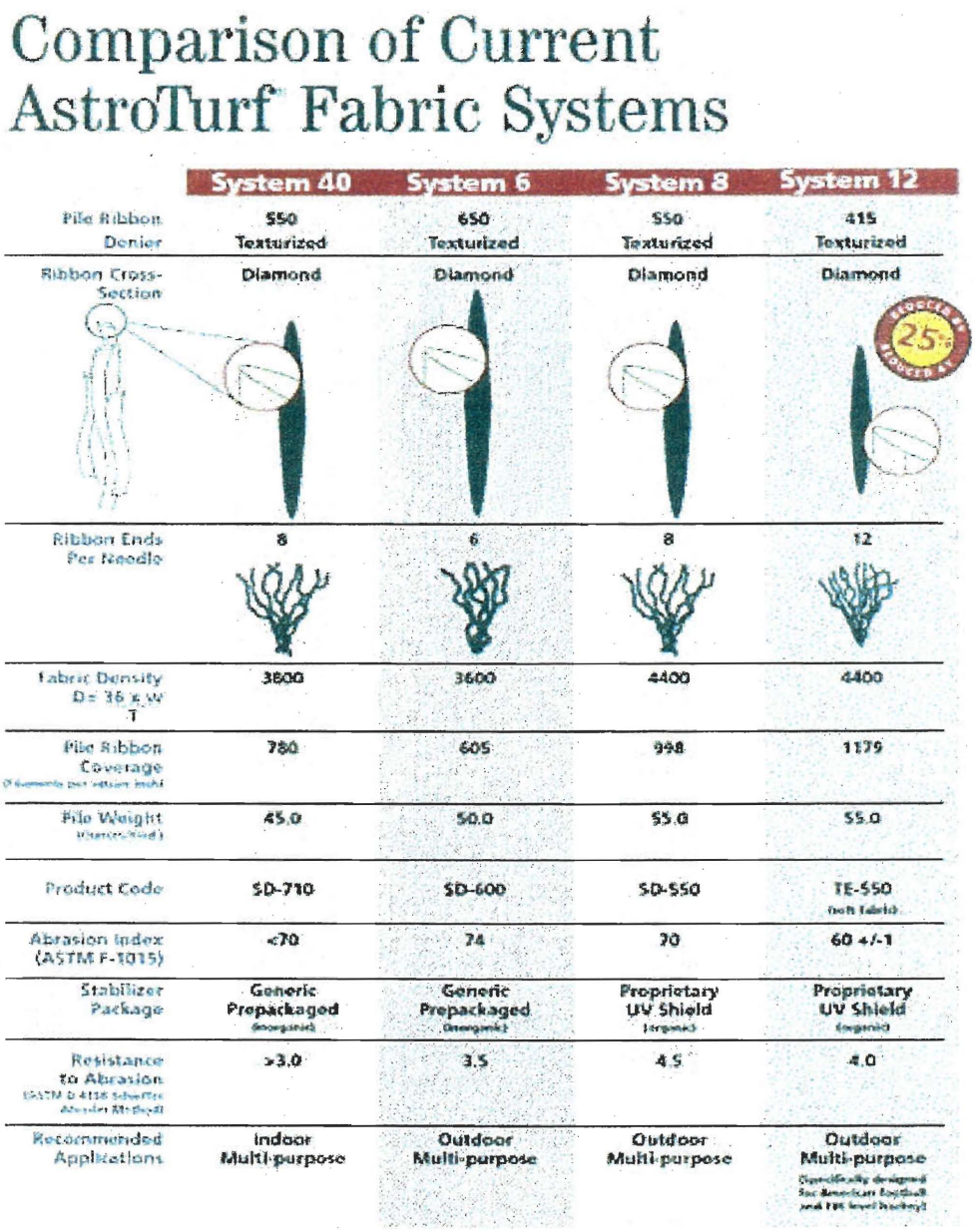
Today, in 1999, AstroTurf is still at the top of the business, but is now under the management of Southwest Recreational Industries, Inc. (SWRI) as they were acquired by Southwest in January of 1994. SWRI has numerous fields around the globe and had its own turf by the name of Stadia Turf. They chose to consolidate this division and combine it with AstroTurf and SWRI has pushed this synthetic systems producer ever since. Currently, SWRI is the world leader in the sports surfaces industry as they install "more than 150 running tracks, hundreds of courts, golf facilities, playing fields and wickets annually" (SWRI AstroTurf Production Page). Because they are so dominant, AstroTurf will tend to be focused on more than other artificial turf producers in this research paper. AstroTurf alone has eight different kinds of turf for all different purposes. Some of those turfs are even specialized for certain sports such as soccer or they are for multi-purpose use.

Although many have gone out of business, there are still quite a few businesses, both national and international, that are creating synthetic turf. Many create turf for such purposes as golf course and various types of flooring as TrueTurf Putting Greens does. Some of the other current manufacturers of synthetic turf that are producing those items today are Grass-Tex, Inc. where Bucky McCamy showed us different samples, Challenger Industries, Inc., NovaGrass International, Inc., GreenTech, Solimento Co, Ltd. and Martin Surfacing in Georgia, which is actually owned by Desso DLW Sports Systems. There are at least half a dozen more that only focus on putting greens for golf. Other companies such as Turf-Tec International, Turf Protection and Turf Equipment Brokers, Inc. have gone on to produce tools only to maintain synthetic turf.

We have given a good view into the industry of synthetic turf and AstroTurf is still the top player after more than 30 years, but what makes their product such a popular choice and are they improving their product where safety is concerned? AstroTurf's two most recent synthetic turf systems are the AstroTurf® 12 XL system, which is installed here at Worcester Polytechnic Institute and its newer AstroTurf® System 2000. Both systems incorporate their new E-layer system which is a rubber base that replaces previously used asphalt and it can be used for multiple generations of turf. AstroTurf also uses what it calls a closed foam shock pad in between the E-layer, which can be seen in Appendix Figure A.6, and the turf fabric that holds the blades. This makes for a softer landing when playing sports such as football. They have also modified their 5/8 inch knitted nylon ribbons (blades) by creating a diamond shaped ribbon that reduces the abrasiveness of the turf and also increases the toughness of the ribbon, which can be seen in Figure 2 (next page) or in Appendix Figure A.3. They claim that their AstroTurf®

System 2000 is the best available system in the industry today and its makeup can be seen in the Appendix Figure A.2 as well as a look at the XL system in Appendix Figure A.1.

Figure 2: AstroTurf Blade System from AstroTurf Information Web Page



Comparison of Current AstroTurf Fabric Systems

	System 40	System 6	System 8	System 12
Pile Ribbon Denier	550 Texturized	650 Texturized	550 Texturized	415 Texturized
Ribbon Cross-Section	Diamond	Diamond	Diamond	Diamond
Ribbon Ends Per Needle	8	6	8	12
Fabric Density D= 36 x W T	3800	3600	4400	4400
Pile Ribbon Coverage	780	605	998	1179
Pile Weight	45.0	50.0	55.0	55.0
Product Code	SD-710	SD-600	SD-550	TE-550
Abrasion Index (ASTM F-1015)	<70	74	70	60 +/-1
Stabilizer Package	Generic Prepackaged	Generic Prepackaged	Proprietary UV Shield	Proprietary UV Shield
Resistance to Abrasion	>3.0	3.5	4.5	4.0
Recommended Applications	Indoor Multi-purpose	Outdoor Multi-purpose	Outdoor Multi-purpose	Outdoor Multi-purpose

Recently, two companies have thrown their hats into the artificial turf ring to attempt to compete with the artificial turf giant, AstroTurf, in the industry of sports

surfacing for sports such as football here in the United States. These companies' names are SprinTurf and FieldTurf. They each have an artificial turf with their respective names on it and are hoping to get the attention of schools and other facilities with their new technology in artificial turf.

SprinTurf is produced by SafTurf International, Inc. as told to us by employee John Chaplin, and they also control the company Turf Protection that was previously mentioned. They are out of Canton, Ohio and call their product the "salubrious" synthetic because they feel it is that much safer and better than the competition's turf. As of early 1999, their product had been installed in just four sites so far with the oldest being just over a year old and their product was still patent pending. Their system has no sand infill and uses "100% resilient materials" so that there is no need for an underpad or asphalt base as this infill and an embedded ground up rubber layer handle all of the shock absorbency (SprinTurf Promotional Booklet). Also, these materials will not allow the turf to expand or contract over time with changes in weather as the turf fibers are attached to it, which is an improvement over artificial turfs of previous decades. There is a small 2-inch sand base underneath these layers which allows for good drainage of water and allows play in rains up to 4 inches of rain per hour. They use a polyethylene fiber carpet with 2-inch blades. They also have a rather unique drainage system along with normal drainage through the sand layer and a cross section of their turf system as a whole can be seen in Appendix Figure A.4.

The other competition for AstroTurf comes from FieldTurf, which has actually been in existence since 1978, but has only recently began to make headlines with its new technology in artificial turf. They manufacture out of two plants that they have in

Georgia and Montreal, Canada. They currently have around 40 fields in place with their oldest one being over 5 years old and with the most recent one being there most important that they have put in to date. FieldTurf recently installed one of their fields at the Division I football school, University of Nebraska. This was a giant step for them to getting exposure as Nebraska football is regularly on television. Their technology is somewhat different than SprinTurf's and has a shock absorbing infill, which consists of graded silica sand and ground rubber. They use a slightly different carpet with polypropylene fibers and 2.5-inch blades. These fibers have been designed to look and feel like grass as can be seen in Appendix Figure A.5. They have also designed the placement of the fibers to imitate grass so that shoes can "easily penetrate, rotate and release, minimizing the chance of motion related injury" and also to take on the look of real grass (FieldTurf Safety Page). Also, a special oil base has been added to the fibers to give the blades a completely non-abrasive and more player friendly touch. They have had no reports to our knowledge of the turf injury foot-lock or abrasion injuries (C1.1). They use 8-18 inches of crushed stone as a drainage system and FieldTurf states that their turf can also be played on safely in up to 4 inches of rain per hour according to their website. They also state that their turf has a life expectancy of 15-25 years as opposed to the usual 10 years for all other turfs.

Both of these companies appear to cost less for installation than AstroTurf so it will be interesting to see if there are changes in the preference of the customers. All three types of turf can be played on in all weather situations and be softer than the grass in certain areas, but they are not all the same and should not be grouped as such. Our opinion is that SprinTurf and FieldTurf is better for preventing abrasion injuries because

of their longer blades, which also end up providing cushion when contact with the turf is made. SprinTurf uses a system which eliminates sand from the infill and coming to the surface where they claim that it reduces the life of the turf, but most of the new models of turf have done away with sand in the infill anyway. FieldTurf appears to have the edge with their turf as their oil base can be found on every blade, which gives it the feel of grass and non-abrasive properties without the loss of traction in dry or wet weather. Also, their national exposure with Nebraska will give them an advantage over SprinTurf as well as their increasing popularity with all coaches, players, and doctors who have come in contact with the turf. For example, Dr. Bill S. Barnhill, M.D. who is an orthopedic surgeon and the U.S. ski team physician said,

> "Unlike grass, FieldTurf provides consistency throughout the year. It will end up being safer than a natural grass field in the long run. Grass wears down, loses its softness and therefore increases the potential for 'foot-lock' or other injuries, as the field develops inconsistencies."

Also, former NFL player, Tim Downing said,

> "I always put safety and playability at the top of my priority list when evaluating field surfaces. FieldTurf has excellent traction in both wet and dry conditions. In one test, wearing only a t-shirt, I ran at full speed and dove stomach first on the turf and did not even receive any abrasions or 'rug burn.' FieldTurf is even better than a well manicured grass field."

As can be seen from these testimonials sent in to their website, FieldTurf is already developing fans. As much as this is good for FieldTurf, where does this leave our athletes? Well, as long as there is competition, there are sure to be more and more improvements in artificial turfs. AstroTurf, FieldTurf, and SprinTurf currently appear to be the best choices for artificial turf, but are they safer and/or "better" than natural grass? Does it cost more or less to install and what about maintenance and replacement over time? Are their injuries that are specific to artificial turf or grass for that matter? Which

playing surface is softer and more shock absorbent? What have these turf manufacturers actually done to improve their product to reduce injuries to athletes, and what options do customers have in the way of such things as underpadding? These are all questions that we will intend to answer or at least elucidate in this paper.

INJURIES

For the purpose of this part of the report, football injuries will be the focus of our attention. The reasons for this are the abundant sources of injury data and studies that have been done in regard to football. We will also concentrate on football in this report because two ex-football players and one current player are writing it.

When domed stadiums started being built, the initial thoughts were happy ones. No one had to sit in the rain, cold or snow to watch a game; the climate in a domed stadium is a controlled one. But this comfort came with a price: the inability to grow grass to play on. Synthetic turf was born. With this new playing surface came the questions of health and safety. While athletes can get hurt on grass, that is a natural material and therefore thought of as a natural sporting injury. On synthetic turf some injuries may be caused by the surface and are therefore artificial injuries, which may be could have been avoided.

Before condemning synthetic turfs and domes let us look at the injuries commonly associated with the synthetic turfs and the way these injuries occur. This way we can possibly see if there is a solution to the problem without getting rid of synthetic turfs altogether.

One such synthetic turf related injury is "turf-toe" The blame for this injury is actually somewhat misplaced. " 'Turf-toe' is generally defined as a sprain to the big toe that results from excessive flexing of the metatarso-phalangeal joint at the base of the toe" (20 most asked questions). This excessive flexing occurs when soft-soled shoes are worn and the athletes make hard cuts on the turf. The reason for soft-soled shoes being worn on turf is due to its flat nature. Soft-soled shoes allow the athlete to plant his foot

completely flat on the synthetic turf and get a larger gripping surface area than on natural grass. Hard-soled shoes are worn on natural grass so as to help avoid sprained ankles on uneven ground. It is also this hard sole that allows the athlete to avoid "turf-toe". The soft soles require the foot to take more of the pressure and force of the cut. A hard-soled shoe, on the other hand, takes more of this pressure in the sole's rigidity, therefore helping to avoiding injury to the foot, even on synthetic turf.

The tearing of the anterior cruciate ligament (ACL) and the medial cruciate ligament (MCL) are thought to happen more often on synthetic turf than on grass. These tears occur when the knee takes a sudden and usually large impact. This impact can occur from a hard landing, a hit or even a hard fall. Since synthetic turf is basically a carpet on asphalt or concrete with little or no padding, it would stand to reason that there would be more frequent large impacts on it rather than on natural grass. But this conception is wrong: most synthetic turf fields are actually softer than natural turf fields (An example of this is a test done on the Georgia Tech football field, shown in Appendix B1). Natural grass fields, believe it or not, have a higher g-max, on average, than do synthetic turf fields. This is probably due to the resilience of new under padding used under synthetic turfs and the lack of resilience of dirt, which simply compacts and hardens over time.

Ankle injuries in general are also considered to be more common on synthetic turf than on natural grass. These injures happen more often on synthetic turf because of the athlete's shoe "locking up" on the turf, while the body turns or twists. Because of the soft-soled shoes, mentioned before, athletes can get better grip to accelerate and decelerate faster, therefore heightening their risk of making hard cuts. On natural grass

fields this can also happen, but only if the cleats are long enough to dig deep into the earth so as to lock the shoe in its plant .d position. It is less likely to have natural grass cause ankle problems in this manner though due to the excessive length of cleat required which is for longer than most athletes would choose to wear.

According to one study it's about forty percent less likely to injure your ankle on natural grass than on synthetic turf, as shown in Table 1. The same report also shows that general injures, non-severe injuries or those that result in less than one practice day missed, are 85% more likely on synthetic turf than on natural grass. This simply shows the abuse done to the athletes' bodies regardless of actual injuries that cause loss of practice time or game play.

Table 1: Injury Epidemiology for Artificial vs. Natural Turf

Site	**Severity**	**A > N**	**A = N**	**A < N**
Knee/ ankle	Severe	41%	45%	14%
Other	Severe	14%	86%	-------
General	Not Severe	85%	13%	2%
A = Artificial Turf N = Natural Turf				

REPORTS

Concern over athletic injuries is an old topic. President Theodore Roosevelt was the first major public figure to stress concern over athletic injuries. President Roosevelt's concerns over frequency and severity of athletic injuries raised enough concern to help start the National Collegiate Athletic Association (NCAA). It has been over ninety years since the formation of the NCAA, whose main concern is to make college athletics safe and fair for all athletes, yet there is still major concern from the media and parents. This continuing concern led the NCAA to form the Injury Surveillance System (ISS).

The Injury Surveillance System is basically a data collection agency. Every school in the National Collegiate Athletics Association has a voluntary choice to submit injury reports on sporting injuries. All these injury reports are then sent to and sorted through, for validity, by the Injury Surveillance System trained staff of athletic trainers and physicians. Also a number of the schools' injury reports are taken into a group for reporting purposes. This group is randomly selected based on a minimum of ten percent from each of the NCAA's Divisions (Division I, Division II, and Division III) and ten percent from each of the NCAA's regions (East, South, Midwest, West), to assure a proper cross-section of national collegiate athletics.

The ISS report we were privy to showed that using football for the purpose of injury surveillance is a wise choice. According to the ISS repot football players are injured at a rate 62% higher than the next most injury-prone sport, wrestling, which is not even played on natural or synthetic turf, the focus of our study. As a matter of fact the next most injury prone sport that *is* played on natural or synthetic turf, is men's and

women's soccer. When comparing men's and women's soccer to football, that football has a 105% higher injury rate than soccer (Appendix B2.22).

Looking at the ISS report concerning injuries on different playing fields, natural turf versus synthetic turf, for football (Appendix B2.12) can be a little confusing at first. It is easiest to look at the average for the two playing surfaces where there is a difference of three and one half injuries per athletic exposure (athletic exposure, A-E, is the equivalent of one player participating in one athletic practice or game; and injury is defined as requiring medical attention by a team athletic trainer or physician and results in restriction of the student-athlete's athletics participation of athletics performance for one or more days beyond the day of injury (Appendix B2.3)). This means a team of only fifty football players practicing five days a week and having one game a week would average one more injury per week on synthetic turf than the same team would on natural grass. In the course of a season, that can be very damning to any team. This would also mean the team has a twenty percent chance of that one extra injured student-athlete being unable to play in the game that week, or at least having his performance somewhat hampered by the injury.

While all this may seem damning to synthetic turf, other reports have different views. In Rob Johnson's Special Report, he states that there is a 20% greater likelihood that a college athlete will have meniscus damage, but this 20%, he also notes, is only a difference from 1.0/1000 to 0.8/1000 (meniscus injuries/athletic-exposures). The same report shows a 40% higher chance of an ankle injury on synthetic turf, as opposed to natural turf. This also is small, considering the overall injury rates were at 0.45/1000 and 0.32/1000 (synthetic turf to natural turf). This example shows that while percentages are

good for some instances, actual numbers are definitely needed to back them up, because percentage comparisons of extremely low injury rates are misleading.

Grass too can be a problem for the athlete. In 1995 the NFL's Cleveland Brown's home opener resulted in nine injuries for the Browns: it was a grass field. The field had been used for a concert and was completely ruined as a usable turf surface six days earlier. The grass was replaced with expensive sod, and was too new and loose for any kind of consistency. Other grass fields that are not maintained properly have been found to have ruts and bare spots on them. These problems can also increase the number of injuries, sometimes to a rate higher than that of synthetic turf, especially since these are not problems on synthetic turf. Ruts are a potential source of ankle and knee injuries, while bare spots usually have increased hardness and decreased traction.

With the desire for increased speed in current football, the question of what body parts are being injured should be addressed. The ISS report (Appendix B2.17) indicates that, 33% of all injuries are knee or ankle related. This raises concerns about the longevity of a player's career as well as his ability to run on an injured leg. Because of these injuries only the best and healthiest athletes can make a NFL career last a decade or more. With the possible increase in injuries on synthetic turf there is no wonder why the NFL's Player's Association tried three time, each unsuccessfully though, to get synthetic turfs deemed a "banned hazardous product" by the Consumer Products Safety Commission.

There is also a consensus opinion among players that synthetic turf is hotter and therefore harder for "big guys" to keep playing all out on for the entire game. And according to a study done at the University of Florida football fields (Appendix B3)

the consensus is right, to a degree. The study was done by the athletic trainers of the university to find out how to help coaches choose better practices times to avoid this temperature problem. While there was an increased temperature on the synthetic turf, as opposed to the natural turf, there was also an increased humidity on the natural turf, as opposed to the synthetic turf. The athletic trainers at the university considered these differences minor enough so as to warrant no overall difference in training schedules on the two surfaces.

While the percentages of injuries are seemingly higher on synthetic turf, the actual injury rates are fairly close. When experts look at these numbers, the differences are considered insignificant. In fact one expert (Dr. James Nicholas, who was the New York Jet's team physician during the full seventeen years of the study) conducted a seventeen yearlong study on injuries and found "no statistical difference" between synthetic and natural turf injuries.

SAFETY IMPROVEMENTS

As previously mentioned in this report, current artificial turf manufacturers are creating developments and making improvements to their respective turf to try and reduce injuries that are occurring on turf. Astroturf has developed what they call a closed foam shock pad, which is supposed to make for a softer landing for athletes when playing sports on AstroTurf. SprinTurf has been able to enter the artificial turf market because they have developed a turf that uses "100% resilient materials", which is supposed to create a surface soft enough that it does not need any underpadding. Finally there is FieldTurf, who has developed a turf that is supposed to be safer for the athlete. FieldTurf has developed a turf that imitates grass in that it allows the foot to rotate and release, therefore it minimizes the chance of a motion related injury. FieldTurf has also developed an oil base that has been added to the turf fibers, which allows the blades to be non-abrasive. The turf companies realize the importance of offering a surface that is friendly to the athletes and therefore are making improvements to their product.

Even though the companies are developing new ideas to try and reduce injuries to athletes playing on their surface there is still one question that remains. That question is, are these improvements actually reducing the number of "turf injuries" occurring to athletes participating on their artificial turf? To answer this question, we chose to look at the injury reports from the trainer's office here at Worcester Polytechnic Institute, which have been included in Appendix B4. We looked at the data from the four sports that play on the artificial turf here on campus, football, field hockey, men's soccer and women's soccer, focusing on the data from the years 1996 and 1997. These two years are important to look at because the school installed new AstroTurf before the 1997 seasons. Looking at the data from those two years, it may be possible to see if the new turf that was installed made any impact on the number of injuries that occurred during practice and competition.

Before we look at the actual data from the two important years we feel it is important to understand the two completely different playing surfaces involved. First it is important to look at the surface that was in place for the 1996 data. In 1996, WPI had an OmniTurf athletic field that had been installed in 1985. The school had decided in 1985 to install an artificial turf field to provide a multifunctional field that could be used by many sports and activities. WPI was the first college in New England to install an OmniTurf field. OmniTurf is unique because it uses a sand formula that penetrates into the fiber layers.

> "The sand provides a cushioning effect similar to natural grass. It is trapped by the fiber so that there is no dispersion, adding to the surface's consistency and preventing loss of sand due to the elements or player's impact. In addition, a built-in drainage system enables water to percolate through the sand and padding to leave the top surface virtually moisture free (1995 Media Guide)."

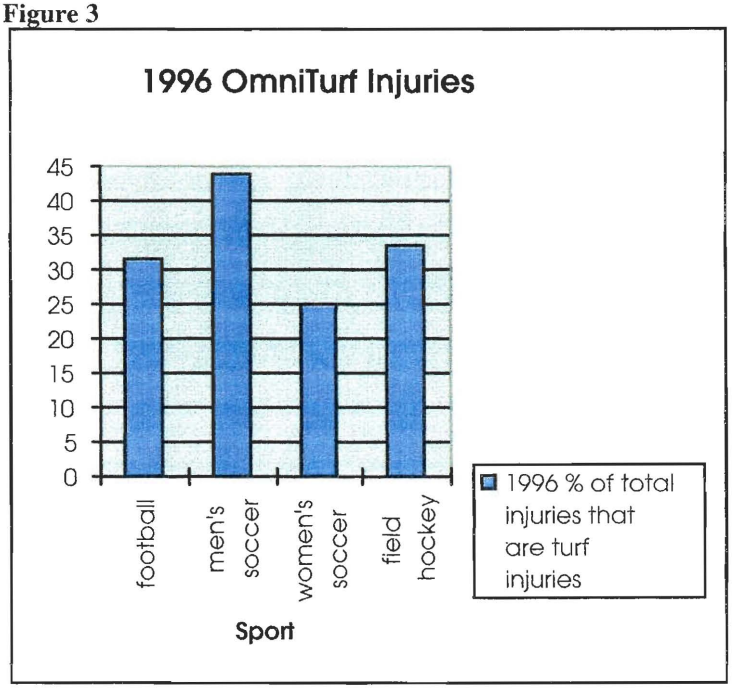
Through eleven years of use, the OmniTurf field had maintained consistent playing conditions, but by 1997, the field had begun to get worn out and the sand was coming through the fibers and were present on the top of the surface. So in 1997 the school redid the field, installing what was at the time, state of the art, AstroTurf 12. AstroTurf 12 was the newest formation of AstroTurf available when it was installed in 1997. It has twelve ribbon ends per needle as compared to eight ribbons ends per needle that had been used in the past. The extra ribbon ends are supposed to give a playing surface that is less abrasive, and more shock absorbent, as well as having less dry traction and more wet traction. The turf here at WPI is supposed to have all these qualities, but it is important to know one thing that differs between the Astroturf 12 here at WPI and AstroTurf 12 fields installed elsewhere. That difference is that the turf here was installed on top of a layer of asphalt, whereas most fields are not underlain by asphalt. Most AstroTurf 12 fields have a layer of a rubber, gravel mix that is under the turf, instead of an asphalt layer that is under WPI's field. The asphalt layer was already there because it was used under the OmniTurf field. Instead of tearing the layer of asphalt up when they installed the new turf, the school decided to leave it in place and install the AstroTurf on

top of the asphalt. The layer of asphalt creates a harder playing surface for our field than is normal for an AstroTurf 12 playing field. An example of this can be seen by just traveling a short distance across town. Worcester State College installed the same AstroTurf 12 a year after WPI did and there is a definite difference in softness discernible just by standing on the surfaces. We had two different people, who had no knowledge of what was underneath, stand on both turf fields, and both people stated that Worcester State's field was much softer than WPI's field. Worcester State's playing field is much softer and that can be explained by knowing that there is that asphalt under the turf here at WPI.

Now that we have explained the differences that exist between the old OmniTurf and the new AstroTurf 12 fields that have been played on at WPI, it is important to look at the actual injury numbers to see if the new AstroTurf has made a difference in the number of injuries that have occurred on the field here. All of the data used to compare the injury numbers from the two different types of turf comes from WPI's yearly injury reports that were given to us from WPI's athletic trainer, Dave Abraham. We looked at the injuries from the four main sports that compete on the artificial turf field. Those sports are football, men's soccer, women's soccer, and field hockey. We were also able to look specifically at injuries that occurred due to the artificial turf, which was also done with the help of Mr. Abraham. We looked at the injuries according to the body part injured and used that to determine turf related injuries, because it is unfair to blame a hand or shoulder injury on the artificial turf surface. The body parts we will be focusing on as turf injuries are, arches in the feet, feet, knee, lower leg, and shins. These are the injuries that can be connected to the playing surface that the athlete was playing on.

Below is a graph representing the data from the injury reports from 1996, playing on OmniTurf, that shows the percentage of injuries for each sport that can be considered turf injuries.

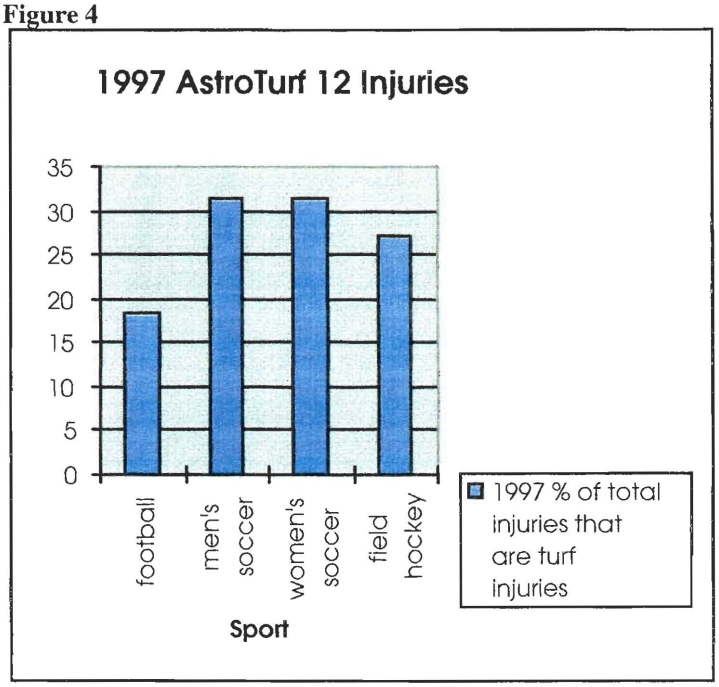
Figure 3



As seen from the above graph the percentages of injuries classifiable as turf injuries ranged from 25% to 43%, depending on the sport. The sport that provides most of the injury data is football. Of the 103 total injuries that occurred in these four sports, 73 of them occurred in football. As a contact sport, football results in more injuries than in other sports. In football, 31.5% of the injuries were turf related. That number is rather high so it is safe to say that the OmniTurf had degraded to the point where it was not a safe playing surface.

Below is a graph of the data representing the percentages of injuries being turf injuries from 1997, which was the first year of the new AstroTurf 12 playing field.

Figure 4



When looking at the data in this graph it is important to compare the numbers to that of the OmniTurf graph. All of the percentages dropped from 1996 to 1997 except in women's soccer. However, it is not surprising that some of the sports did fluctuate because with the exception of football, all of the other sports have rather low injury numbers to begin with, so if there is just one more injury that occurred the percentages will fluctuate dramatically. Because there are over 100 football injuries that occur each year, football provides a solid data base. With that in mind the percentages of turf injuries to total injuries that occurred in football dropped from 31.5% in 1996 to 18.3% in 1997. That is almost a 50% reduction in turf injuries occurring on the new AstroTurf 12, compared to the old OmniTurf field. The number of total football injuries stayed constant, 73 in 1996 and 71 in 1997, but the actual number of turf injuries that took place dropped from 23 to 13. That is a dramatic decrease in turf injuries, which shows that the

new AstroTurf was a big improvement on the old turf. Another statistic to look at is the number of practice injuries that occurred. Practice injuries are important because in a sport like football, more than 3/4 of the time spent competing by the athletes occurs in practices rather than in games. The athletes practice 4 times a week but only play a game once a week, although injury data from games is sparser than that because not all games are played on "home" turf. That means that the majority of the players' time is spent in practices. When looking at the number of practice injuries that occurred in the two year period, practice injuries dropped by 13 when playing on the AstroTurf. On the OmniTurf there were 41 football practice injuries that occurred, while on the AstroTurf there were only 28 football practice injuries.

Manufacturers are definitely trying to create a playing surface that is safer for the athlete to play on. In our study, we found that injury numbers were dramatically reduced when playing on the newer artificial turf. The old OmniTurf field that had been installed 1985 did the job it was intended to do, by limiting maintenance requirements. However, the old fields are just not capable of competing with the newer softer and less abrasive artificial turfs that are out on the market today when it comes to reducing injuries. The AstroTurf 12 surface that was installed in 1997 showed dramatic improvements over the OmniTurf, in the number of turf injuries that occurred during the sports that use the turf field. This shows the athletes and consumers that the new technologies and developments that turf manufacturers are coming up with are making a difference in providing a safer playing field for today's athletes.

Equipment

An important factor to consider when looking at artificial turf is the specific equipment needed to play on it. In a sport such as football there is considerable contact between the athlete's body and the playing surface. Playing football well requires sudden movements and rapid stops, starts, and turns. Falling is an integral part of the sport. Protective gear designed for use on artificial turf is available and effective.

Covering the skin is paramount to avoid "turf burns". Protective sleeves covering the section from the athlete's mid-forearm to up over the elbow are very helpful because they cover the athlete's elbow and protect him from the "turf burns" that can be received through sliding on artificial turf. A combination scrape/friction burn is the result. Turf burns can be painful and normally take over a week to heal. The sleeves help reduce turf burns by covering the athlete's elbow, which normally breaks the fall when a player is knocked off balance or lunges. Protective sleeves are typically not required equipment, but it is our personal experience that they are effective.

The most important piece of equipment that requires matching to the turf surface is shoes. There are different types of shoes that can be worn and the decision of what kind to wear is based on the type of artificial turf and the weather conditions. There are four main types of shoes designed for participating in football. Two types are worn on only turf, while one can be worn on either turf or grass, and the last one is worn only on grass.

Figure 5 shows one type of "turf" shoe. This shoe is actually just a basketball shoe. It is worn on a dry artificial turf surface. It has a smooth sole and also is comfortable because it has padding on the inside. The padding makes the athlete's foot comfortable because the shoe is softer and the foot does not feel as much impact when running. When an artificial turf field is dry there is enough friction between the sole and the turf that there is no need for any cleats on the bottom of the shoe. Therefore the basketball shoe has adequate traction and is comfortable.

Figure 5: Basketball Shoe

The second shoe, shown below in Figure 6, is also worn on artificial turf. It can be worn on any type of turf and in most weather conditions. It has numerous small knobs on the sole, which gives it more traction on the artificial turf than a smooth basketball shoe would have. This enables the shoe to be worn when the turf is wet. The one drawback of this shoe is that it does not have as much padding as the basketball shoe, so it is not as comfortable. It represents a tradeoff of comfort for traction when conditions demand it.

The third type of football shoe, shown in Figure 7, can be called the hybrid. It is worn on both artificial turf and grass. It was designed to be a shoe worn on turf when it becomes slick, from rain or snow, but is also worn on grass when the ground freezes and gets hard. The sole has many longer spikes on it, which gives the shoe a high level of traction on artificial turf. That traction is too high to be worn when the turf is dry, but

make it useful when the weather conditions are a little less than ideal. The spikes are also long enough to give the athlete enough traction when playing on grass. However, the

Figure 6: Turf Shoe

shoe is the least comfortable of the turf shoes, due to the little padding that exists inside. This creates a shoe that is mostly worn only out of only necessity, during bad weather conditions.

The fourth and final type of football shoe, shown on a following page in Figure 8, is used on only grass. The shoe has seven strategically located spikes to give the best traction, while playing on grass. These spikes are located in pairs in the heel, two pairs around the ball of the foot, and one lone spike at the tip of the sole. With the lower number of spikes on the sole, more pressure is put on each spike. This can be uncomfortable because of backpressure when the surface is too firm. The spikes are also much longer than those on other shoes, which enable them to dig into the grass and give the athlete the proper traction that is needed to compete. The shoe gives the athlete

traction on grass, but it is uncomfortable, especially when the ground is hard, but the athlete needs to wear them for the traction when playing on a grass field.

Figure 7: Hybrid Shoe

There have been studies done that look at the different type of shoes worn during football competition to see if they make a difference on the athlete wearing them. One study compared performance in the shoe types we described. The study looked at these shoes with an 11.35-kg axial load on synthetic turf under wet and dry conditions and on natural grass. All of the shoes were tested on all of the surfaces, even if they were not designed to be used on that surface. The cleated shoe, similar to the fourth shoe above, was tested on the artificial turf, even though it would not be used on artificial turf. Likewise the court shoe, similar to the first shoe above, was tested on natural grass, even though it was understood that it is not designed to give any traction on grass.

Figure 8: Grass Shoe

The study revealed that: "Shoes tested in conditions for which they were not designed exhibited reproducible excessive or extreme minimal friction characteristics that may have safety implications (Heidt et al., 1994)". The study confirmed that shoes mismatched with conditions could result in injury. The study also "urges shoe manufacturers to display suggested indications and playing surface conditions for which their shoes are recommended (Heidt et al., 1994)". This recommendation is especially important to dissuade athletes from picking shoes solely for comfort, which could prove dangerous later.

COST ANALYSIS

Now that we have been through the current reports and studies, we have shown that there does not appear to be any concrete evidence that is significantly damning to either artificial turf or natural grass as a playing surface. We can agree with the statement that "according to the latest studies funded by the NFL, NCAA, and National Athletic Trainers Association, there is 'no statistical difference' between injuries suffered on artificial turf and natural grass" (New Canaan Fact Sheet). This makes the process of determining which playing surface has the greater cost benefit easier as injuries and their costs to schools, parents, and institutions would undoubtedly have to be taken into consideration if one of the surfaces decidedly caused more injuries. From our analysis, cost per injury on each type of surface is equivocal. This allows for an easier analysis of the costs that are involved for anyone considering creating a playing surface of grass or artificial turf. With injuries aside, which playing surface is the "better" of the two economically?

The first costs that occur for either type of surfaces is the installation of and the initial capital costs for the surface, which is the most important and costly part of the project. As in our other analyses, we will use AstroTurf, FieldTurf, and SprinTurf as our primary examples. As is always the case, the installation costs for artificial surfaces are much higher than that of natural grass (C1.1). Beginning with installation and construction of the field, all of the surfaces vary in profile. Natural grass requires excavation, installation of irrigation and drainage systems, sand, loam, and the sod layer. This must all be done while giving the grass a slight pitch of –1% for drainage of water. SprinTurf is much more complicated as seen before because they have multiple small

layers that must be put down correctly. FieldTurf and AstroTurf are not as complicated, but still are costly and time consuming as can be seen in Table 2. A full analysis of these four playing surface's construction profile and other information can be seen in Appendix section C1 as the firm Pressley Associates did this analysis for North Kingstown High School in North Kingstown, Rhode Island.

Table 2:	**Construction Profiles**		**PRESSLEY ASSOCIATES**
SOD	**SPRINTURF**	**FIELDTURF**	**ASTROTURF**
Sod layer	Polyethylene fiber carpet	Polypropylene fiber carpet	5/8" knitted nylon ribbon with synthetic
12" rootzone mix	with 2" blades	With 2.5"	Fiber backing adhered to a closed cell
60% sand	Synthetic rubber infill mixture-1"	2" rubber/sand infill mixture	Foam pad cushion.
40% loam	2" porous sand with rubber under	8"-18" crushed stone base (depth	10" Drainage layer
Subdrain	Carpet	Varies with subdrainage profile)	Typical subgrade
Typical subgrade	Free Draining Geotextile Membrane	Typical subgrade	
	6"-12" Porous Stone		
	Underdrainage system		
	Typical subgrade		

With the analysis/checklist AstroTurf has done that can be seen in Appendix C2 as a guideline, we can look some of the costs associated with maintaining the playing surface. For artificial turfs, there will be a large initial capital cost for equipment such as vacuum sweepers, line stripers, and painting templates. For these, fuel, paint, paint solvents, and water will be needed as well as manual labor to run machines and keep the field looking in peak condition. There are also future capital costs because no artificial turf field will last forever and will have to be replaced. A useful service life of the surface should be determined, and this usually pertains to the manufacturers warranty. Because the base will need only little rework or repairs, replacing the artificial surface should take less time and cost far less than the initial installation. Another positive of

artificial turf is the fact that sometimes "old" turf has a resale or salvage value. The only other future costs are those having to do with maintaining and buying new equipment.

Unfortunately for natural grass enthusiasts, grass maintenance costs are much higher than artificial turfs. Initially, natural grass has costs associated with the contractor maintaining the field during its growth period. Grass also requires numerous products to maintain it such as fertilizer, fungicides, pesticides, and other chemicals such as lime. It will also need striping paint, fuel for the equipment, and grass seed and/or re-sodding materials. There is a much higher annual maintenance cost when labor is factored in because of the large need for field repairs after usually a mere 6 football games into the season. It is also possible that with a large amount of rain and a football game that the turf will be unrecognizable after one game so the labor needed for repairs tends to be much higher. Natural grass also requires future capital costs such as equipment replacement and possible field tarp replacement if one is used, as well as repair or replacement of drainage and irrigation systems.

After a lot of generalization, let us put some numbers to these costs by comparing artificial turfs to natural grass. Using the North Kingstown High School project, we see that AstroTurf is by far the most costly throughout the process with natural grass being the least costly. AstroTurf's initial cost is more than four times that of natural grass at more than $1.1 million as seen on the next page in Table 3. All of the artificial turf's initial costs are at least twice that of grass, but grass has an annual maintenance cost that is four times any artificial turf. There is also a large variety in replacement costs of the turfs and grass. It is important to note that the replacement of sod occurs after 4 years whereas artificial turf lasts for 10-12 years on the average. For replacement

considerations, it is not as economical to adopt AstroTurf, as their replacement costs are more than 3 times the other two types of artificial turf.

Table 3:	Costs			PRESSLEY ASSOCIATES
Typical Costs:	**SOD**	**SPRINTURF**	**FIELDTURF**	**ASTROTURF**
Initial	$260,000	$600,000	$725,000	$1,1340,000
Yearly Maintenance	$20,000/Year	$5,000/Year	$5,000/Year	$5,000/Year
Replacement	$34,000/After 4 Years	After 10-12 Years - $250,000	After 10-12 Years - $250,000	After 10-12 Years - $770,000
Total Costs Over 13 Years	$622,000	$915,000	$1,040,000	$1,968,500

There is also a good assessment that can be seen in detail in Appendix C3 that goes over a 24 year economical assessment between prescription natural turf, natural turf, and synthetic turf. As this chart done by AstroTurf shows, natural turf is once again the least costly over 24 years, but marginally, and the prescription natural turf, which is specially treated grass, is extremely costly. Once again, there is a very noticeable difference in the costs of maintenance with synthetic turf at $53,741, natural turf at $937,234, and prescription natural turf at an extreme $1,746,574.

As has been shown, natural turf is the least costly in most, if not all cases over any given period when compared to any artificial turf or prescription natural grasses. It then seems obvious that grass should always be the choice when creating a playing surface, but there is one thing that has not been taken into account. The factor that has not been taken into account is the usage and playability of the surface all year around. According to Dr. Robert T. Bronzan, "Directly related to the actual cost of a stadium playing surface is its availability".

Indeed, natural grass fields have a maximum usage of 30-50 games or events that can be held on them before conditions have deteriorated to the point of possible unsafe playing conditions. Any grounds crewman of the past or present would agree that "no matter how sophisticated the grass system, use must be restricted" (McGraw, 1991). All artificial turfs, however, can be used all year around and have an unlimited number of annual uses. Natural grass surfaces tend to be restricted areas when games are not in progress on them, but artificial surfaces can be open to the public or be used for multiple team use for practice and games during the day. Artificial turf can also be used for many other kinds of events besides sports such as band concerts, band practices, and graduations. One case of greatly improved usage comes from South High School in Pittsburgh, Pennsylvania where they had a grass field that was only used 19 times per year. They installed an artificial turf system in 1987 and now they hold more than 1600 events per year (C4.1).

Since we have the costs of maintenance and installation as well as the usage limits of each type of surface, we can go further to look at the actual cost per event of each surface type. AstroTurf did this in their 24 year analysis of themselves and two types of grass giving the grasses 33 uses per year and themselves a bold 500 uses annually. This translated into costs per use of $6,045 for prescription natural turf, $2,233 for natural turf, and a paltry $160 per usage of the field on synthetic turf. This is one case where some bias may have been involved. Another analysis that can be seen in the Appendix C5, where both grass and synthetic turf are given a 10 year life-span and number of uses per year are given as 50 and 150 respectively. Cost per use then ends up being $1,100 for natural grass and $683 for the synthetic turf. It is interesting to note that if the synthetic

turf was only used 50 times as well then the cost would have been $2,050 per use. The last example is the least biased of all as Pressley Associates also did this analysis giving sod a gracious 60 games per year and 360 for each of the three artificial turfs (C1.1). All surfaces resulted in less than $1,000 per use, but sod was still almost twice as expensive as AstroTurf, around three and a half times that of FieldTurf, and more than four times that of SprinTurf. Once again, if the uses were the same, even SprinTurf would be more costly than natural grass. What all of these analyses say is that an artificial turf field is only cost effective if it will be in use more often then the current grass field(s) at that location.

Grass proponents might say that if plenty of grass fields to handle all of these events are available, artificial turf cannot save much money when it costs so much to install. They may have a point, but they fail to realize the revenue potential with artificial turf. An artificial turf field can hold multiple events per day and that can translate into big money for the institution with ticket sales as well as refreshments sales. With artificial turf, it eliminates the need for many grass fields as well as the maintenance costs that they quickly accumulate. At the Pittsburgh South High School, other teams from around the city from all sports would use their field and tournaments would also be held there, which increases the revenue of the school. Similarly, here at WPI, central Massachusetts high schools play for the SuperBowl championship in football on our very field. Using Pressley Associates numbers, it would only take 100 people at $2 per ticket for a football game to be beneficial to the school. Natural grass would take almost 400 people to equal its cost per use. With changes in ticket prices, the field can pay for itself

very easily and bring profits at the front gate where food and refreshments have not even been taken into account yet.

This all goes to show that if cost is the only factor involved in the decision, then most artificial surfaces are better choices than sod. Specially treated natural grasses such as prescription natural grass are much too costly. It can also be used so many more times without any increase in maintenance and this eliminates the need for many grass fields as all teams can share the field at different or the same times. Artificial turfs will need a greater initial capital cost, but those surfaces will pay for themselves just by the volume of events that it can hold throughout the day and year. This will, of course, be saving money on maintenance as well as making money from other sources associated with more events that can be held on that site.

"EXPERT" OPINION

An important factor in the evaluation of artificial turf is the opinion of those who work on it. We were able to find this out through putting together a survey that asked athletic trainers and coaches for their input. A sample of the survey can be found in Appendix D. We defined these people as experts because each had several years of experience with artificial turf. Athletic trainers have treated injuries that have occurred on turf, and have training and knowledge in kinesiology and anatomy. Coaches can be considered experts because they have coached athletes participating on artificial turf for a number of years, and before they were coaches, they were players who competed on a variety of turf surfaces. Through their years of coaching football, these professionals have seen many injuries occur on turf and on grass. In addition, two of the coaches surveyed have degrees in sports medicine, so that they could also take the trainers' perspective. We surveyed 4 coaches, two with sports medicine degrees, and 1 trainer: Dennis Bruck, assistant football coach at WPI; Jeff Lane, assistant football coach at WPI; Chris Robertson, assistant football coach at WPI; Tim Smith, assistant football coach at WPI; Dave Abraham, head trainer at WPI.

The first question we asked was whether they thought that artificial turf causes more injuries to occur than grass does. The answer to this question was unanimous. They all felt that more injuries occurred because of artificial turf. The second part of this question was, why they felt that way about artificial turf. In response, we received a variety of answers such as, "turf does not give as much as grass when contact is made" or "the body gets more fatigued playing on turf which causes muscles and joints to be less receptive." But the one thing that is mentioned on almost all of the surveys is that artificial turf has a "velcro-like" grabbing effect on the athletes feet. This effect is attributed to the fact that artificial turf has such high traction, which leads to feet getting caught in the turf and not being able move when the athlete's legs twist. Another interesting response to this question came from the athletic trainer. He stated that he felt

that athletes have to learn how to run and learn how to stop and go while playing on turf. Athletes can maneuver quickly without worrying about their feet getting caught up when playing on grass, but when playing on turf the athletes must remember to pick their feet up completely when starting to move, otherwise the foot is likely to stick to the turf surface due to the higher traction.

The next part of the questionnaire asked our experts to give examples of injuries they feel occur more often on artificial turf than on grass, excluding turf burns. All of the answers we received to this question dealt with leg injuries. The most common response was injuries to knee ligaments, such as ACL, MCL, LCL, PCL. The explanation was that when a leg twists relative to the foot, the most likely part to give way is the knee. The twisting of the leg puts extra pressure on the knee ligaments and when pushed too far, the ligaments can stretch or tear. Other injuries that were mentioned in responses were; joint pain in the ankles, knees, and hips that is caused by the extra pounding the body takes, dislocations caused from landing on the turf, and concussions from hard landings of the head on the turf. The other part of this question asked their opinion as to why these types of injuries occurred on artificial turf. The two most frequent responses were that the turf has high traction level which leads to the grabbing effect on the athlete's feet, and that the turf does not give as much on impact, which creates a harder playing surface.

For the next question we wanted to get the overall opinion of what our experts felt about artificial turf. We asked whether they thought it was a good thing or a bad thing. The responses we received usually equivocated. Most of the responses stated that depending on perspective, artificial turf could be good or bad. The positive aspect was from an administrative standpoint, which stressed turf's lower maintenance needs and maintenance costs. However, the same people also stated that artificial turf is bad from the players' standpoint. The only good thing that was stated about artificial turf from the players' standpoint was that turf is consistent and flat, when compared to a grass field. However, our experts felt that it was not a good thing because of the increase in injuries

that occur on it, in addition to the extra "wear and tear" that the body is put through from playing on it. Because coaches are administrators to some degree, it is not surprising that they have mixed feelings about artificial turf. Whether it be from an administration standpoint or from the players' standpoint.

The last section of our questionnaire involved putting together a multi-attribute model to see whether grass or artificial turf is the best overall choice. We asked them to rank five different aspects of a playing field from 1 to 5, with 1 being the most important to them. Then for each aspect they chose whether they felt that grass or artificial turf was the better choice for meeting that criterion. By weighting each aspect depending on how important it is to that particular person, we were able to calculate whether grass or artificial turf is the better choice. When the calculations were done all but two of those surveyed were in favor of grass over turf, and the two people that were not in favor of grass were less than ten points away from choosing grass, but those that chose grass did so by a wide margin. Below is the model that shows the average numbers taking into account all that were surveyed.

Table 4: Multi-Attribute Model

Aspect	**Average weight given to aspect**	**People choosing Turf**	**Total Turf points (weight x people)**	**People choosing grass**	**Total Grass points (weight x people)**
Low maintenance cost	16%	5	80	0	0
Less injuries occur	33.33%	0	0	5	166.65
Softer & more shock absorbent	24%	1.5	36	3.5	84
Looks are more pleasing	8%	2.5	20	2.5	20
Performs well in all conditions	18.67%	2.5	46.675	1.5	28
		Totals:	**182.675**		**298.65**

As seen in the above table, when taking the average numbers from everyone surveyed the choice is grass by a drastic margin. The most important aspect to everyone surveyed was that "less injuries occur" with a weight of 33.33%. This helped to lead the people to choosing grass because not only did it have the highest weight, but also everyone agreed that grass was the superior surface for injury reduction. Our respondents chose grass over artificial turf by more than 100 points, or greater than 150% of the points given to artificial turf. Coaches and Athletic trainers chose grass because in their view, it limits injuries although it increases costs.

Through our survey that was passed out to our "experts", we discovered that artificial turf does have an image of being a more dangerous surface to play on. The experts responded by giving us examples of injuries that they felt occurred more times on turf than on grass. They also gave us their educated view of why those injuries take place on turf. We also found that an overall opinion of whether artificial turf is good or bad depends on what perspective you look at it from, and finally we found through our multi-attribute model that our experts would choose a grass surface over an artificial turf surface by a large margin, when we took into account the most important aspects of what is involved in a playing field. The perception that artificial turf causes more injuries is pervasive among athletic professionals, but other data did not support this view, as other sections of this report will attest. The facts are that even though a few major colleges have converted from natural grass to artificial turf playing fields in the last decade, many more have converted from grass to artificial turf because of the aforementioned benefits.

CONCLUSIONS AND RECOMMENDATIONS

Artificial turf proved to have many pros and cons when compared to natural grass. We found that there appeared to be two main factors when determining which type of playing field to install: cost and injury statistics.

We found that those who had played, coached, and medically treated those injured on artificial turf, prefer natural grass. They have developed the perception that artificial turf is more dangerous to athletes. In our research-based opinion, this perception comes from the fact that certain injuries are *blamed* on artificial turf, whereas, when the same exact injury occurs on a grass field, it tends not be attributed to the surface, but to an outside source such as nature. Occasionally, clusters of injuries are attributed to artificial turf, but some clustering is a statistical certainty. Clusters of injuries that occur on ill-maintained grass fields are more likely to have a determinable cause. Our research concurs with reports and studies that conclude there is currently "no substantial statistical difference" in the overall injury rates on those surfaces.

We discovered that those who have no physical daily contact with the playing surface prefer the most cost beneficial surface and tend to be ignorant to the "user's perception" of artificial turf. Our research also shows that from this cost analysis standpoint, artificial surfaces will always be the better long-term investment where the field will be under heavy usage. Even though artificial turf has a larger initial cost, it requires very low maintenance and can be used year-round. This allows for any institution to make more money from having more venues on their field that allows for more admission and refreshment sales, which is a bonus on top of the lesser cost per event that currently exists with artificial surfaces.

Our recommendation is that for any institution considering the two types of playing surface, they should determine how much usage they desire out of the field. If they desire more than 50 uses per year or usage all year-round, then an artificial turf

surface should be chosen for installation; otherwise, a natural grass surface will suffice. Injury rates should not be a consideration in the selection, as we have found them to be nearly equal for both surface types.

REFERENCES: PRINT SOURCES

Bronzan, Dr. Robert T. 1982. Synthetic Versus Natural Turf. *School Business Affairs* April 1982: 18 – 20.

Hassard, Geoff. 1995. WPI Engineers Football Media Guide.

Heidt, Robert S., Jr., MD, Stephen G. Dormer, Patrick W. Cawley, OPA, RT, Pierce E. Scranton, Jr., MD, Gary Losse, MD, and Mark Howard, ATC. 1996. Difference in Friction and Torsional Resistance in Athletic Shoe-Turf Surface Interfaces. *The American Journal of Sports Medicine* Vol. 24, No. 6: 834 – 841.

Keene, J. S., MD, R. G. Narechania, MS, K. M. Sachtjen, MD, and W. G. Clancy, MD.1980. Tartan Turf® on Trial. *The American Journal of Sports Medicine* Vol. 8, No. 1: 43 – 47.

Johnson, Rob, MD. 1996. Special Report: Lawnmowers or Vacuum Cleaners?; The Role of Artificial Turf. *Sports Medicine in Primary Care* September 1996: 1 – 4.

Leach, Richard. 1998©. Synthetic Turf Multiplies Stadium Use. *AstroTurf Booklet: Usage – Articles/Studies/Reports.*

McGraw, Mike. 1991. Point/Counterpoint: Synthetic Turf. *Athletic Business* September 1991.

Nigg, B. M. and B. Segesser. 1988. The Influence of Playing Surfaces on the Load on the Locomotor System and on Football and Tennis Injuries. *The American Journal of Sports Medicine* Vol. 5: 375 – 383.

Slaughter, Janice K. 1995. Personal letter to James Siegle at Southwest Recreational Industries, Inc. in *AstroTurf Booklet: Injury – Articles/Studies/Reports* August 1995.

REFERENCES: OTHER PRINT SOURCES

20 Most Asked Questions on Injuries Related to Synthetic Turf. 1998. *AstroTurf Booklet: Injury – Articles/Studies/Reports.*

AstroTurf Booklet: Injury – Articles/Studies/Reports, 1998.

AstroTurf Booklet: Usage – Articles/Studies/Reports, 1998.

NCAA Injury Surveillance System Report for the 1994-95 football season.

New Canaan High School "Rams" All-Purpose Athletic Field Fact Sheet. 1998. *AstroTurf Booklet: Injury – Articles/Studies/Reports.*

Pressley Associates Report prepared for North Kingstown, Rhode Island High School, 1998.

SprinTurf Promotional Booklet. 1998. *SprinTurf: The Ultimate Evolution of Artificial Turf.*

REFERENCES: WORLD WIDE WEB PAGES

www.artificialturf.com/ -- SprinTurf Homepage.

www.astroturf.com/ -- Southwest Recreational Industries, Inc. Homepage.

www.astroturfmats.com/home.htm – AstroTurf Doormats and Rolls.

www.fieldturf.com/ -- FieldTurf Homepage.

www.grass-tex.com/ -- Grass-Tex, Inc. Homepage.

www.muhlenberg.edu/sports/astro.html – Muhlenberg College Analysis of AstroTurf.

APPENDIX A

Illustrations: Turf Cross-Sections and Turf Components

Figure A.1: AstroTurf XL

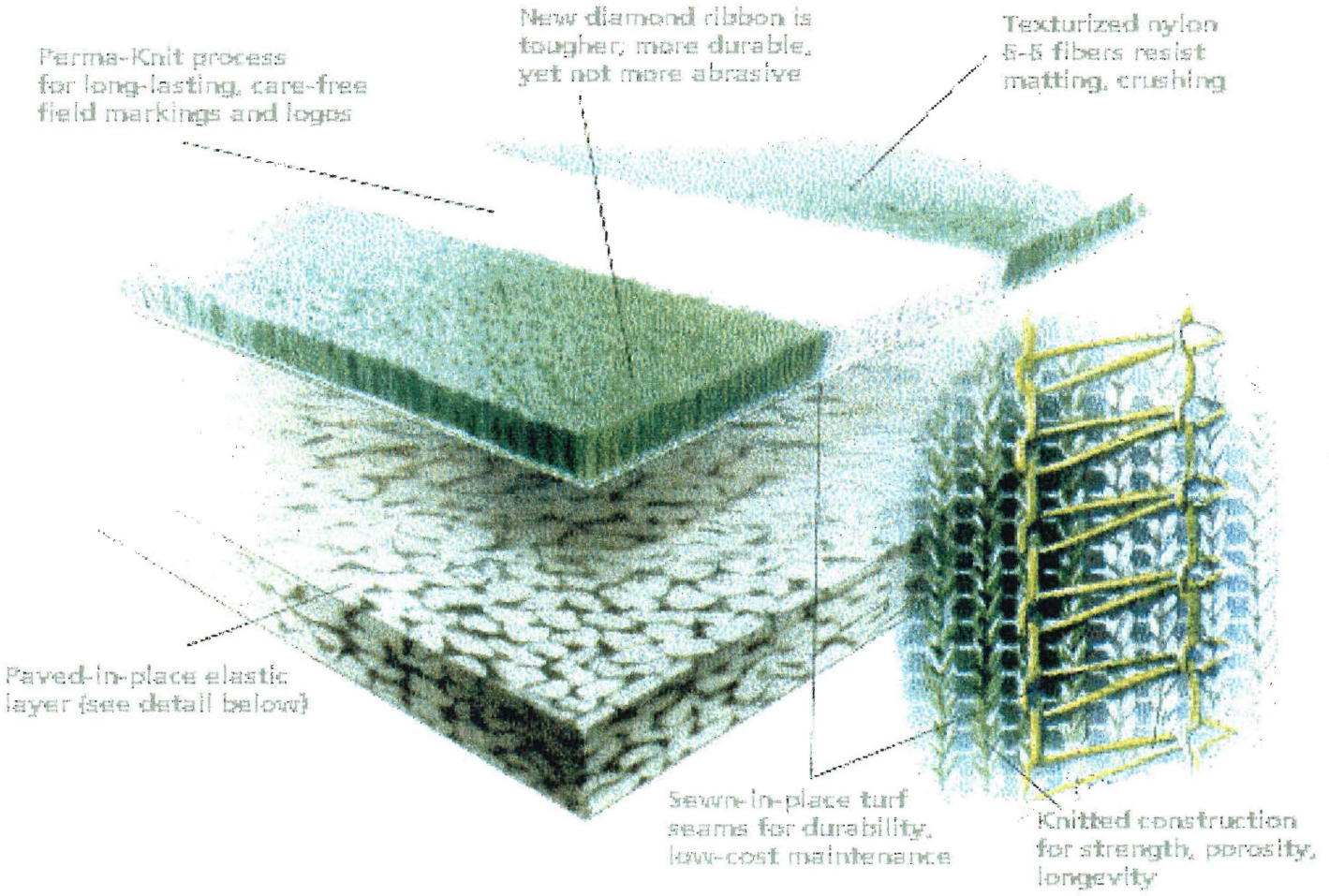


Figure A.2: AstroTurf System 2000

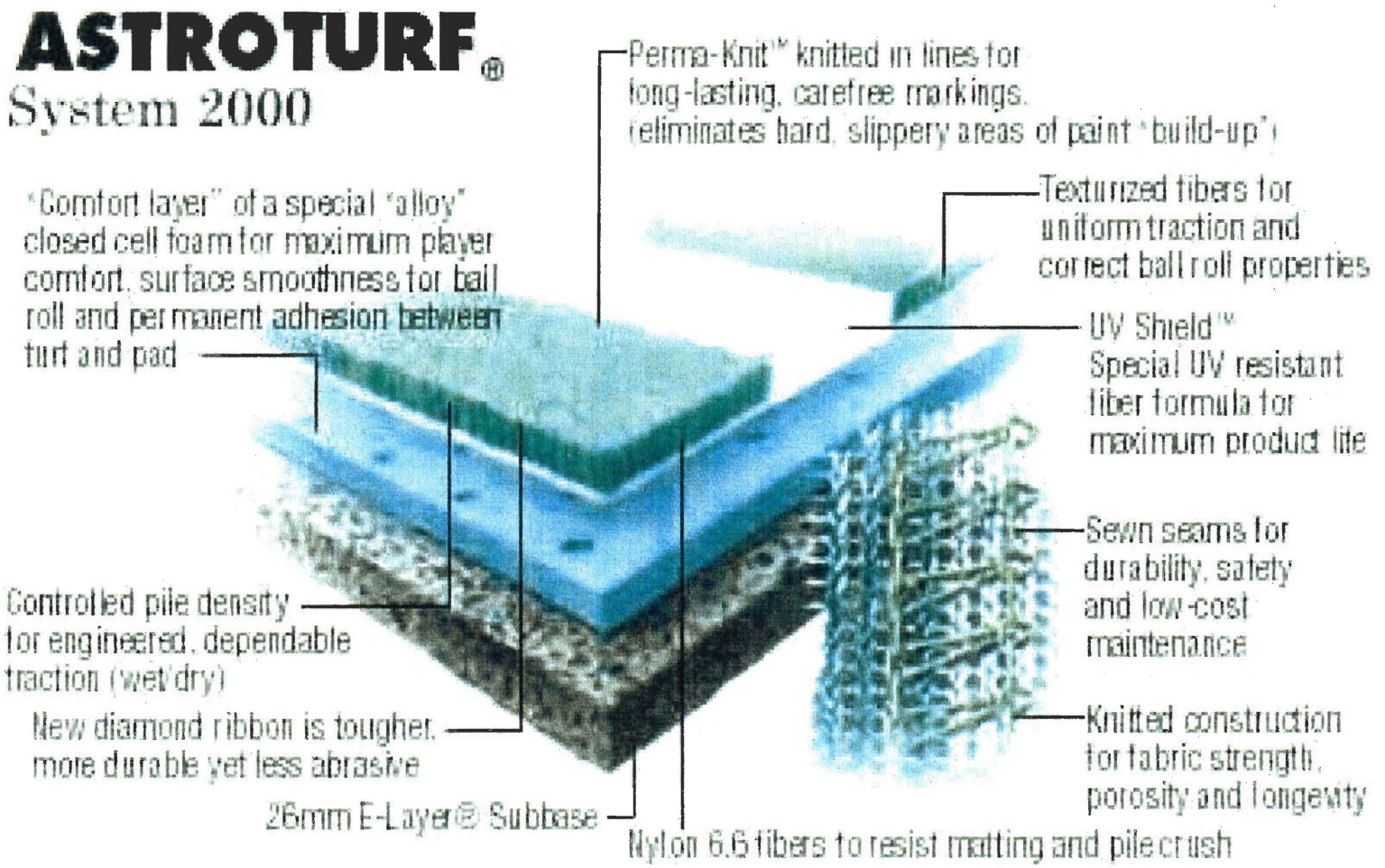


Figure A.3: AstroTurf Blade System

Comparison of Current AstroTurf® Fabric Systems

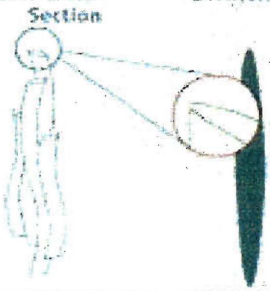
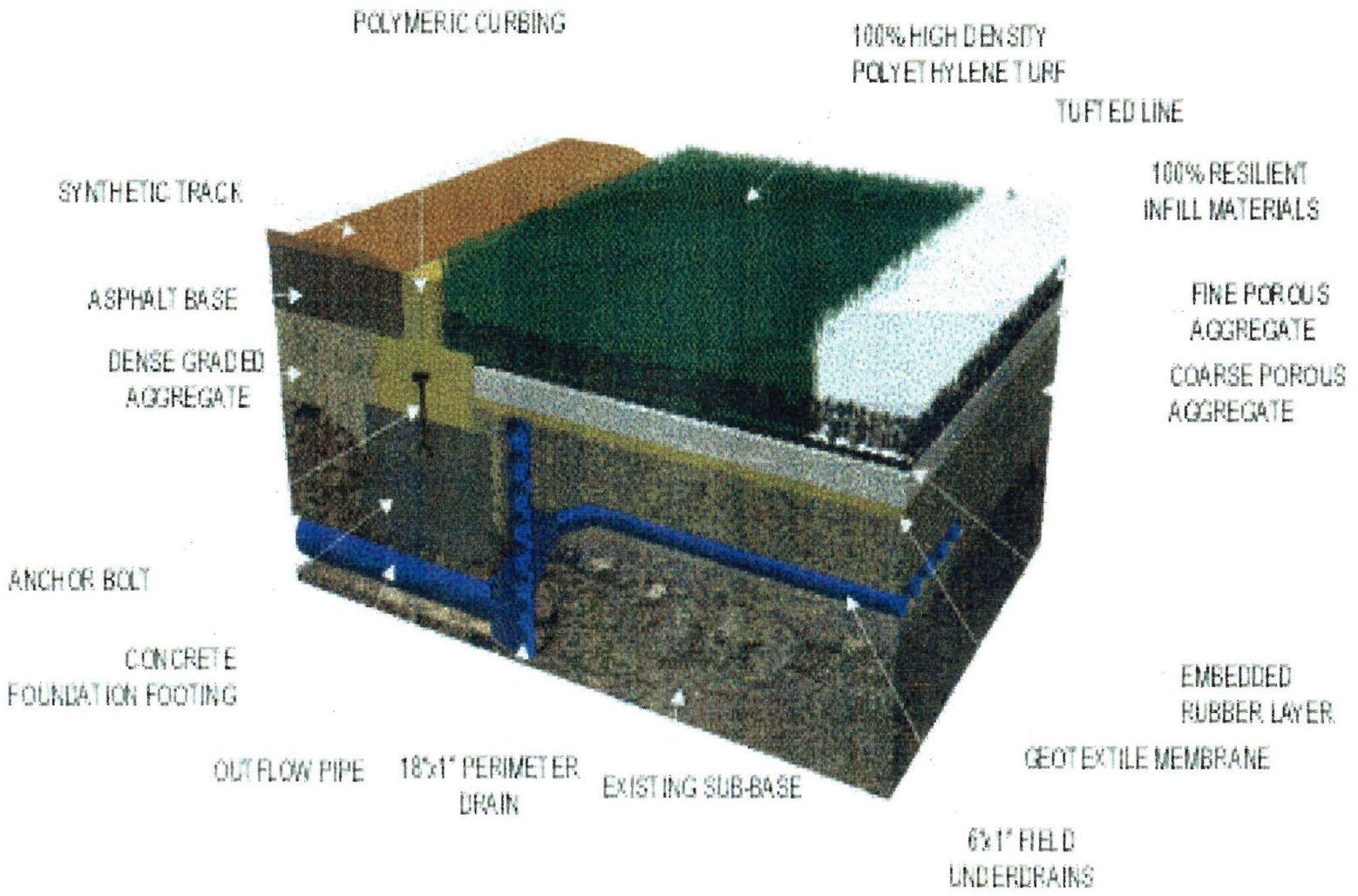
	System 40	System 6	System 8	System 12
Pile Ribbon Denier	550 Texturized	650 Texturized	550 Texturized	415 Texturized
Ribbon Cross-Section	Diamond 	Diamond 	Diamond 	Diamond 
Ribbon Ends Per Needle	8 	6 	8 	12 
Fabric Density D= 36 x W T	3800	3600	4400	4400
Pile Ribbon Coverage	780	605	998	1179
Pile Weight	45.0	50.0	55.0	55.0
Product Code	SD-710	SD-600	SD-550	TE-550
Abrasion Index (ASTM F-1015)	<70	74	70	60 +/-1
Stabilizer Package	Generic Prepackaged	Generic Prepackaged	Proprietary UV Shield	Proprietary UV Shield
Resistance to Abrasion	>3.0	3.5	4.5	4.0
Recommended Applications	Indoor Multi-purpose	Outdoor Multi-purpose	Outdoor Multi-purpose	Outdoor Multi-purpose

Figure A.4: SprinTurf



AstroTurf
SINCE 1965

August 24, 1995

Mr. James Siegle
Southwest - AstroTurf
809 Kenner Street
Dalton, GA 30721

Dear Jim:

A field inspection was performed on the Georgia Tech natural turf field in Atlanta, GA. The inspection and field impact tests were conducted by Patrick Gorham on August 16, 1995 at 10:00 AM. The natural turf field is bordered with Polypro (PP-650/C-25D) artificial turf system and at two test drop areas averaged 97 Gmax.

On the natural turf areas impact tests were performed according to ASTM F-355-A test method at 6 representative locations on the field. Air temperature was measured at 88°F. Impact values are listed below and also shown in the attached graphs.

	Drop Locations	Gmax Average
1.	West side line (center) in bound.	121
2.	Center of field.	122
3.	South side between center of field and goal line.	118
4.	South center goal line in bound.	128
5.	Northeast area of field.	142
6.	Northeast corner in bound.	144
	Natural Turf Field Average	129 Gmax
	Range	118 - 144

The impact average result for natural turf is 129 Gmax and the average result for artificial is 97 Gmax.

Sincerely,

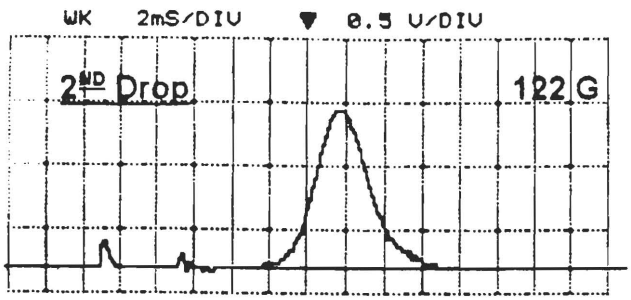
Janice Slaughter

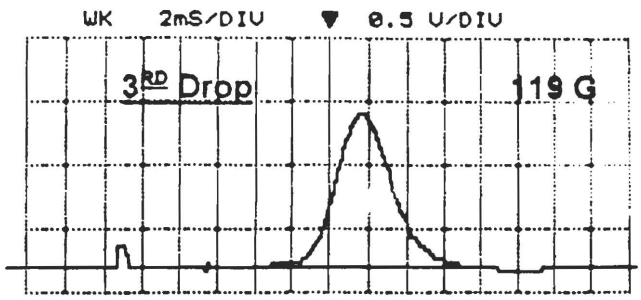
Janice K. Slaughter
Technical Field Coordinator

809 Kenner Street
Dalton, Georgia 30721

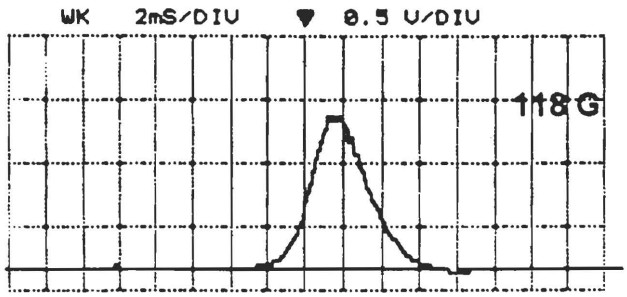
(800) 723-8873
(706) 272-4200
fax (706) 278-4898

3/16/95
Location
1.

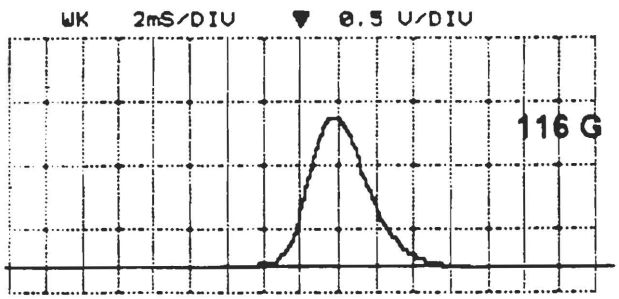


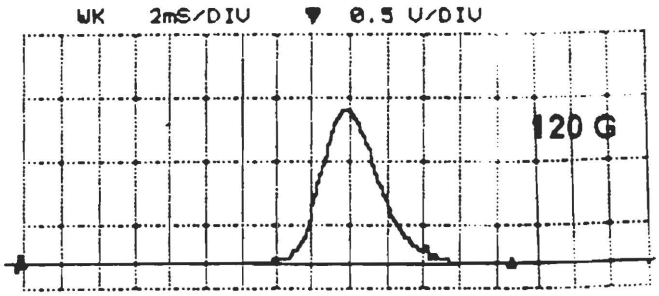


2.

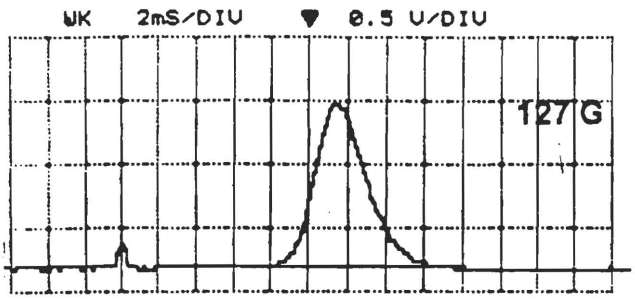


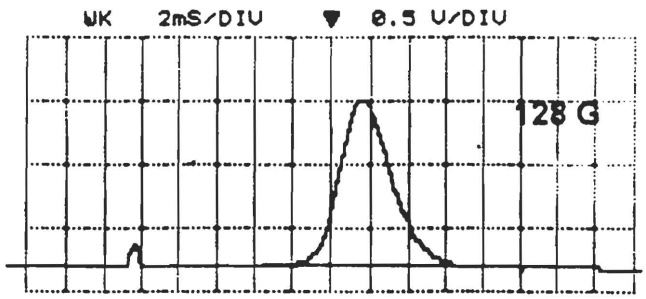
3.



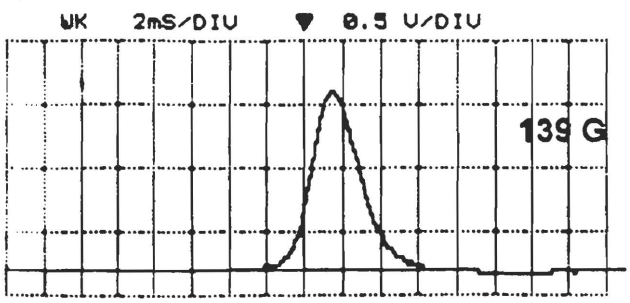


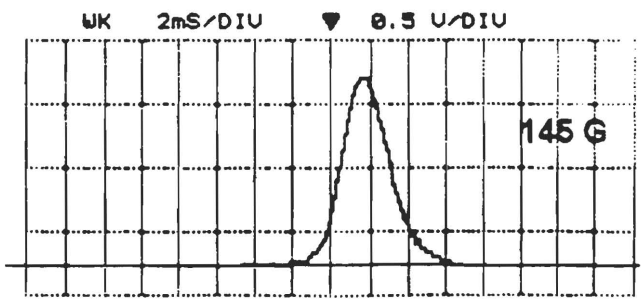
4.



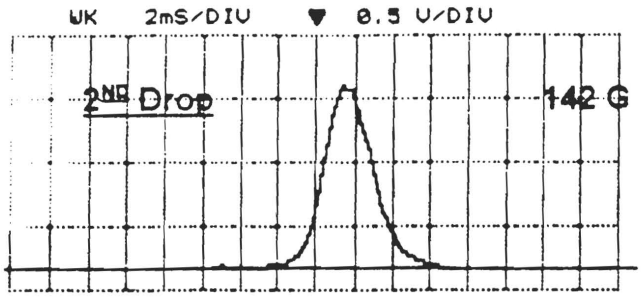


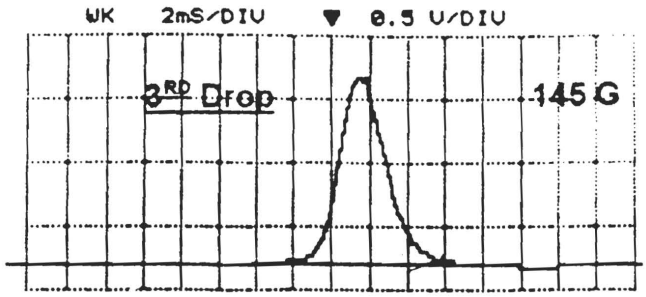
5.





8/16/95
Location
6.





WPI's Athletic Trainer's Injury Reports for 1996 & 1997

BODY PART / SPORT REPORT

DATE - 01/03/97

BODY PARTS	Baseball	Basket Men	Basket Wom	C C M&W	Field Hoc	Football	Golf	Soccer Men	Tennis Men	Tennis Wom	Track Men	Track Wom	Softball	Swim Men	Swim Wom	Volleyball	Wrestling	Crew Men	Crew Wom	Icehockey	Lacros Men	Lacros Wom	Rugby Men	Rugby Wom	Ski Men	Ski Wom	Soccer Wom	Other	*Totals
Abdomen			1													1													2
Ankle		1	3	1	1	12		3								1					1						1	5	29
Arches				1																							1		2
Arm						1																							1
Back		1				5		1											1								1	1	10
Elbow	1					3											2												6
Fingers						2												1											3
Foot		1				5		1																					7
Forearm						2																							2
Groin					1	2		1									1										1		6
Hamstring						2				1																	1		4
Hand														1			1												2
Head		1				1							1				1						1					3	8
Hip		1				2		1																					4
Illness						2																							2
ITB				1																									1
Knee		1	1	4	1	16		4						1			3				1		1					2	35
Lower Leg					1	2		1																			1		5
Neck						4																							4
Quadreceps				1	2	9		2																			2	1	17
Ribs								1																				1	2
Shins				1				1																					2
Shoulder						8								1		2	1			1								1	14
Thumb						4																							4
Totals	1	6	5	9	6	82		16			1		1	3		4	9	1	1	1	2		2				8	14	172

B4.2

1996

DATE - 01/03/97

A L L C O U N T S / S P O R T R E P O R T

DESCRIPTION	Baseball	Basketball Men	Basketball Wom	C C M&W	Field Hoc	Football	Golf	Soccer Men	Tennis Men	Tennis Wom	Track Men	Track Wom	Softball	Swim Men	Swim Wom	Volleyball	Wrestling	Cr Ew Men	Cr Ew Wom	Icehockey	Lacros Men	Lacros Wom	Rugby Men	Rugby Wom	Ski Men	Ski Wom	Soccer Wom	Other	* Totals
Practice	1	2	3	7	3	41		8			1		1	1		4	3	1	1				1				3	2	83
Competition		1	1	2	3	32		8									3			1			1				5		57
Other		3	1			9								2			3				2							12	32
Occurred	1	6	5	9	6	82		16			1		1	3		4	9	1	1	1	2		2				8	14	172
Acute	1	3	3	7	5	74		12			1		1	2		2	9	1		1	2		2				8	12	146
Chronic		2	1	2	1	6		3						1		1			1									2	20
Reoccurrance		1	1			2		1								1													6
Injury Is	1	6	5	9	6	82		16			1		1	3		4	9	1	1	1	2		2				8	14	172
Hospital		1											1														1	1	4
Physician		1	1	1		10		2						1			4		1				1					1	23
Infirmary			1																										1
P. T.																													
Surgery		1															1											2	4
None	1	3	3	8	6	72		14			1			2		4	4	1		1	2		1				7	10	140
Referral	1	6	5	9	6	82		16			1		1	3		4	9	1	1	1	2		2				8	14	172

B4.3

1996

DATE - 07/28/98

BODY PART/ SPORT REPORT

BODY PARTS	Baseball	Basketball Men	Basketball Wom	C C M&W	Field Hoc	Football	Golf	Soccer Men	Tennis Men	Tennis Wom	Track Men	Track Wom	Softball	Swim Men	Swim Wom	Volleyball	Wrestling	Crew Men	Crew Wom	Icehockey	Lacross Men	Lacross Wom	Rugby Men	Rugby Wom	Ski Men	Ski Wom	Soccer Wom	Other	* Totals
Abdomen											1																	1
Achilles				1	1	1					1																1	1	6
Ankle		5	2	1	1	11		4		1	1	2				1	4		1		4	2	1				3	8	52
Arches		1	2			2		1							1			1									1		9
Back	2	1	2	2	1	4		1	1		1				1		2	3				1						3	25
Chin						1																							1
Ear																	2												2
Elbow	4					1							2			1	1				1							2	12
Eye			1			1																						2	4
Face																												1	1
Fingers	1					6																	1					1	9
Foot			4			1		1				1										2	1					4	14
Forearm						5											1												6
Groin	2		1		1	1																					1		6
Hamstring	1	1			1	1		2			2																	1	9
Hand														1															1
Head		1	1			3							1															1	7
Hip		1	2	1	1	4		2																			1		12
Illness			1			4										1													6
ITB			2	2																								1	5
Jaw																1													1
Knee		2	3	4	1	6		3	2	1		1	2			1	5	1	1		1		1				3	4	42
Lower Leg	1	1	2	2		4											3	1									1	3	18
Mouth & Teeth																	1												1
Neck		1				3											1												5
Nose		1			1												1												3
Quadreceps		1	1		1	5		2			1		2				1			1		1					2	1	19
Ribs					1	2					1						3			1									8

DATE - 07/28/98

B O D Y P A R T / S P O R T R E P O R T

BODY PARTS	Baseball	Basket Men	Basket Wom	C C M&W	Field Hoc	Football	Golf	Soccer Men	Tennis Men	Tennis Wom	Track Men	Track Wom	Softball	Swim Men	Swim Wom	Volleyball	Wrestling	Cr Ew Men	Cr Ew Wom	Icehockey	Lacros Men	Lacros Wom	Rugby Men	Rugby Wom	Ski Men	Ski Wom	Soccer Wom	Other	* Totals
Shins			2	1	2						1																		6
Shoulder	4	3	1			10			1		3			1	3	3	3		1	1	1		1				1	9	46
Skin																											1		1
Thumb					3	6											1						1						11
Toe						3		1								1													5
Wrist						3				2			1															2	8
Other			1			1							1		1			1			1	1					1	2	10
Totals	15	19	28	14	15	89		17	4	4	12	4	9	2	6	9	29	7	3	3	8	7	6				16	46	372

DATE - 07/28/98

ALL COUNTS / SPORT REPORT

DESCRIPTION	Baseball	Basket Men	Basket Wom	C C M&W	Field Hoc	Football	Golf	Soccer Men	Tennis Men	Tennis Wom	Track Men	Track Wom	Softball	Swim Men	Swim Wom	Volleyball	Wrestling	Crew Men	Crew Wom	Icehockey	Lacros Men	Lacros Wom	Rugby Men	Rugby Wom	Ski Men	Ski Wom	Soccer Wom	Other	* Totals
Practice	8	6	14	12	5	28		12	3	2	6	2	3		6	4	20	5	2		3	2	1				8	6	158
Competition	3	7	6	1	6	43		4					3	1		1	7	1		2	3	5	2				8	1	104
Other	4	6	8	1	4	18		1	1	2	6	2	3	1		4	2	1	1	1	2		3					39	110
Occurred	15	19	28	14	15	89		17	4	4	12	4	9	2	6	9	29	7	3	3	8	7	6				16	46	372
Acute	13	17	22	9	13	82		16	4	4	11	3	7	2	6	7	26	7	3	3	8	7	6				15	43	334
Chronic	1	1	4	4	1	6		1				1	1			1	2										1	2	26
Reoccurrance	1	1	2	1	1	1					1		1			1	1											1	12
Injury Is	15	19	28	14	15	89		17	4	4	12	4	9	2	6	9	29	7	3	3	8	7	6				16	46	372
Hospital	1	1	1		1	8				2	1		1				3				1		1				2	8	31
Physician	4	3	5	1	1	28		1	1	1	1	1	4			2	6				1		4				1	7	72
Infirmary			1		1	2										1							1					2	8
P. T.																													
Surgery						1																							1
None	10	15	21	13	12	50		16	3	1	10	3	4	2	6	6	20	7	3	3	6	7					13	29	260
Referral	15	19	28	14	15	89		17	4	4	12	4	9	2	6	9	29	7	3	3	8	7	6				16	46	372

APPENDIX C

Cost Analysis

C1 Pressley Associates Report

C2 Cost Analysis Check List – Natural Grass vs. Synthetic Turf

C3 24 Year Economic Assessment

C4 Case History; South High School

C5 Natural vs. Artificial: Per Use Cost Comparison

COST ANALYSIS MATERIALS

PROPOSED HIGH SCHOOL ATHLETIC FIELD SURFACING
NORTH KINGSTOWN, RHODE ISLAND
SEPTEMBER - 1998

PREPARED FOR NORTH KINGSTOWN HIGH SCHOOL
NORTH KINGSTOWN, RI BY **PRESSLEY ASSOCIATES**
432 COLUMBIA STREET CAMBRIDGE, MA 02141

PRODUCT TYPE:	**NATURAL TURF**	**ARTIFICIAL TURF**		
DESCRIPTION:	**SOD ON ROOTZONE MIX**	**INFILLED ARTIFICIAL GRASS**		**ARTIFICIAL GRASS CARPET**
Based on 81,000 sq. Ft	**WITH IRRIGATION**			
tpe. soccer field				
BRAND NAME	**SOD**	**SPRINTURF**	**FIELDTURF**	**ASTROTURF**
CONSTRUCTION PROFILE:	Sod layer	Polyethylene fiber carpet	Polypropylene fiber carpet	5/8" knitted nylon ribbon with synthetic
	12" rootzone mix	with 2" blades	with 2.5"	fiber backing adhered to a closed cell
	60% sand	Synthetic rubber infill mixture-1"	2" rubber/sand infill mixture	foam pad cushion.
	40% loam	2" porous sand with rubber under	8"-18" crushed stone base (depth	10" Drainage layer
	Subdrain	carpet	varies with subdrainage profile)	Typical subgrade
	Typical subgrade	Free Draining Geotextile Membrane	Typical subgrade	
		6"-12" Porous Stone		
		Underdrainage system		
		Typical subgrade		
TYPICAL COSTS:				
Initial	$260,000	$600,000	$725,000	$1,134,000
Yearly Maintenance	$20,000/YEAR	$5,000 PER YEAR	$5,000 PER YEAR	$5,000 PER YEAR
Replacement - Sod/turf only	$34,000/AFTER 4 YEARS	AFTER 10-12 YEARS - $250,000	AFTER 10-12 YEARS - $250,000	AFTER 10-12 YEARS - $770, 000
TOTAL COSTS OVER 13 YR.	$622,000	$915,000	$1,040,000	$1,968,500
PLAYABILITY				
Number of Games per year	Maximum: 60	(Unlimited) Maximum: 360	(Unlimited) Maximum: 360	(Unlimited) Maximum: 360
COST PER EVENT	$797.00	$195.50	$222.00	$420.00
YEARS ON MARKET	Natural Product	Oldest installation is 1 year old,	Oldest installation is 5 years old,	Early 1970's
		located in Canton, Ohio	located in Ontario	
		6 fields under construction	38 fields in place (18 in 1997)	
ADDITIONAL NOTES	Minimal additional cost	The poly-propylene/polyethylene blend	The poly-propylene/polyethylene	Designed specifically for multipurpose
	Natural renewable resource	fibers split above the infill layer, and knit	blend fibers split above the infill layer,	athletic and recreation needs.
	With appropriate maintenance,	together to hold the infill mix in place.	and knit together to hold the infill mix	Performs well in any climate or weather
	grass is the most common	As there is no solid/semi base, rain drains	in place. As there is no sold/semi-	conditions.
	surface safe for play comfortable.	right through. Field is playable in	solid base, rain drains right through.	Increased number of revenue producing
	Cost of maintenance will increase	situations of up to 4" per hour of rain.	Field is playable in situations of up to	events.
	with increased use of the field.	Footing doesn't deteriorate. Manufacturer	4" per hour of rain. Footing doesn't	
		claims rubber mix is non-abrasive, feels	deteriorate. Manufacturer claims	
		that sand mixes of similar products is	sand/rubber mix is non-abrasive. No	
		abrasive, and that abrasiveness shears off	reported incidences of foot-lock or	
		fibers at the surfaces, reducing life-span.	abrasion injuries.	
		Sand mixtures under carpet compact to		
		hard surface.		
	Information based on manufacturers propaganda.			

AstroTurf

LIFE CYCLE

COST ANALYSIS CHECKLIST – NATURAL GRASS VS. SYNTHETIC TURF

A. NATURAL GRASS (CELL-SYSTEM, SAND BASE)

1. INITIAL CAPITAL COST

a. Excavate existing site, install new drainage and irrigation systems, install sand fill and grow grass (seed/sod).
b. Provide necessary equipment to operate and maintain the system.
c. Cost for contractor to maintain field during initial growth period.

2. FUTURE CAPITAL COST

a. Periodic equipment replacement – can be handled by periodic purchase or as an annualized cost on a depreciation basis.
b. Periodic replacement of irrigation and drainage piping, equipment, etc.
c. Periodic replacement of field tarps.

3. ANNUALIZED COST

a. Materials – per functional estimates for frequency of use, quantity, unit cost, etc.

____ Water
____ Fertilizer
____ Fungicides, pesticides
____ Other chemicals – lime
____ Striping paint, vegetable dyes
____ Fuel, oil, etc. to operate equipment
____ Seed and/or re-sod materials

b. Labor – estimated man-hours per function, frequency/function, wage rates to perform/apply materials, related functions plus mowing, aerating, divot replacement, area sod replacement, reseeding, etc.

c. Equipment

1. Per either a periodic replacement basis or annualized depreciation basis to develop costs for owned equipment.
2. Rental equipment cost projections must also be included. Items may be needed such as:
   a. Portable cranes to remove goal posts, portable stages, etc.
   b. Aeration, sod cutting equipment, etc., used periodically – may be rented rather than owned.

B. SYNTHETIC TURF

1. INITIAL CAPITAL COST

a. The initial cost for the field must include excavation, paving, drainage and installation of synthetic turf.

b. Operating Equipment:

____ Vacuum sweeper ____ Line striper ____ Painting templates

2. FUTURE CAPITAL COST

a. Field Replacement – Determine useful service life interval. Subbase repairs/rework should be minimal at the time of replacement. "Old" turf may have resale, salvage value.

b. Operating/maintenance equipment replacement either per capital cost or per annualized depreciation.

3. ANNUALIZED OPERATING COST

a. Materials – Per function, frequency of use, quantity, unit cost, etc., the estimated cost for:

____ Paints ____ Fuels – to operate equipment

____ Paint solvents ____ Adhesives – first echelon maintenance

____ Water – periodic wet-down and/or field washing

b. Labor – per function, frequency, man-hours, usage rates, etc.:

____ Sweep field ____ Touch-up painting

____ Wet/wash-down field ____ Restriping

c. Equipment – replace periodically on capital basis or annual depreciation.

C. UNIT COST BASIS PER USAGE

For each alternate:

a. Determine total life cycle cost.

b. Divide (a) by number of years of service life (cycle) to obtain average annual cost

c. Determine quantity of events by type, number of hours/type event, number of participants/type event.

d. Determine unit cost:

____ Annual cost/event

____ Annual cost/operating hour

____ Annual cost/participant hour of use

24 Year Economic Assessment

Items	Prescription Natural Turf	Natural Turf	Synthetic Turf
Initial Cost of Football Field	$750,000	$536,400	$882,000
24 Years of Maintenance	$1,746,574	$937,234	$53,741
Heating of Grass	$1,477,871	----	----
Tarp Cover	$15,000	----	----
Vacuum System	----	----	$30,000
12 Year Vacuum Overhaul	----	----	$13,842
12 Year Turf Replacement	----	----	$622,905
24 Year Total	**$3,989,445**	**$1,473,634**	**$1,602,488**
Uses Per Year	**33**	**33**	**500**
Cost Per Use	**$6,045**	**$2,233**	**$160**
Extras			
Foam Pad	----	----	$100,000
Foam Pad 12 Year Replacement	----	----	$138,423
Shoes	$0	$0	$0
Protective Equipment	$0	$0	$0
Logo Painted	$0	$0	$0

Item	Maintenance Description	Cost
1.	Average yearly cost of maintenance:	
	Mowing	$10,000
	Fertilizer, 3 times per year, 1,200 lbs.	5,000
	Water with automatic system	6,000
	Overseeding twice per year	3,000
	Markings for 6 events per year	3,000
	Miscellaneous cleanup; spring & fall	4,000
	Subtotal	$31,000
2.	Repair work:	
	Sodding of excessively worn areas (30 yd. to 30 yd., between hash) 1,000 sq.yd. at $3.00	$3,000
	Re-crown of field	2,000
	Subtotal	$5,000
3.	Maintenance/replacement/major overhaul of automatic watering system	$5,000
4.	Repaint field markings and vacuuming	$2,000
5.	End of useful life – replacement of artificial turf and repair underlayment	$450,000

Note:

Items 1, 2, and 3 pertain to natural grass surfaces
Items 4 and 5 pertain to synthetic surfaces

AstroTurf

CASE HISTORY

SYNTHETIC TURF LETS SOUTH HIGH EXPAND YEARLY FIELD USAGE FROM 19 FOOTBALL GAMES TO MORE THAN 1600 EVENTS

The field at South High School in Pittsburgh was a heavily worn inner city grass field used only 19 times a year for football. In 1987 synthetic turf was installed. Now in its fifth season, the turf is just starting to show some signs of wear.

The South High turf field is maintained by a Tennet Sweeper, Model #240, which was also new in 1987. By October 1991, the sweeper had 3.037 hours on it. At an average of 40 miles for each hour, the total sweeper usage equals 121.480 miles.

What does that mean in field usage time?

In the last five years, approximate use of the turf included:

- Duquesne intramural sports from 7:30 – 11:30 p.m. daily
- Usage by all 10 city football teams, and Central Catholic, Duquesne and Carnegie Mellon teams
- Two National Drum and Bugle Corps Shows for two years
- Site of the Pennsylvania Interscholastic Athletic Association (PIAA) State Football Play-Offs for three years

Approximate regular yearly activities:

August through December

- 1 Jr./Sr. Football Game
- 1 Band Concert
- 4 Softball Games
- 6 Soccer Games
- 7 JV Football Games
- 8 Scrimmages
- 48 Football Games
- Gym Class from 8 a.m. to 2 p.m.
- Daily Band Practice
- Football Practice
  South High School from 2:30 to 5 p.m.
  Duquesne from 5 to 8 p.m.

SOUTH HIGH EXPANDS USAGE

March through August

- 4 Softball Play-Offs
- 1 or 2 Graduations
- 6 Soccer Play-Offs
- 12 Lacrosse Games
- 12 Baseball Games
- 12 Track Meets
- 115 Community Softball Games
- Gym Class from 8 a.m. to 2 p.m.
- Baseball Practice from 2:30 to 5 p.m.
- Track Practice from 2:30 to 5 p.m.

Approximate 5 Year Use:

- 4 Drum and Bugle Corps
- 10 Graduations
- 10 City Band Concerts
- 35 JV Football Games
- 40 Football scrimmages
- 60 Soccer Games
- 60 Baseball Games
- 60 Track Meets
- 60 City Softball Games
- 60 Lacrosse Games
- 200 Band Practices
- 264 Football Games (Varsity & College)
- 400 Baseball and Track Practices
- 575 Community Softball Games
- 1,000 Football Practices
- 5,400 Gym Classes

Total of 8,238 Different Events in Five Years!

Natural vs. Artificial

Per Use Cost Comparison

Natural Grass

$$\frac{\$300{,}000}{\text{Initial Cost}} + \left[\frac{\$25{,}000}{\text{Annual Maintenance Costs}} \times \frac{10}{\text{Expected Years of Use}}\right]$$

$$\frac{50 \times 10}{\text{Annual \# Events} \times \text{Expected Years of Use}}$$

Synthetic Turf

$$\frac{\$975{,}000}{\text{Initial Cost (w/ Subbase)}} + \left[\frac{\$5{,}000}{\text{Annual Maintenance Costs}} \times \frac{10}{\text{Expected Years of Use}}\right]$$

$$\frac{150 \times 10}{\text{Annual \# Events} \times \text{Expected Years of Use}}$$

$1,100 Cost Per Use **vs.** **$683** Cost Per Use

Explanation and Example:

Cost for a natural grass field ranges from $300,000 and up. Maintenance begins at $30,000 and can go as high as $100,000/year. Industry standards for expected years of use for synthetic turf is 10 years, maintenance is $5,000/year, including the cost of a sweeper prorated over 10 years. A useful size for a multipurpose field is 75,000 sq. ft., with subbase costs conservatively estimated at $4.00/sq. ft. Turf cost is figured at $9.00/sq. ft.

APPENDIX D

Survey

IQP Survey Looking at Artificial Turf and Injuries

1) Please write your name and occupation:

2) How much knowledge of artificial turf would you consider yourself having?

3) In your opinion do you think artificial turf causes more injuries to athletes than grass?

Why or Why not ?

4) Can you give any examples of injuries that occur more often on artificial turf than on grass. (other than turf burns)

What do you think the reasoning is for these injuries occurring more on artificial turf?

5) What is your overall opinion of artificial turf? Do you think it is good or bad? Why?

6) Please rank these five statements from 1 to 5 according to importance to you. (1 being the most important) And put next to each statement whether you think grass or artificial turf is better at meeting that statement's requirement.

a) Low maintenance cost
b) Less injuries occur
c) Softer and more shock absorbent field
d) Looks are more pleasing
e) Performs well in all conditions